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OSTEOLOGY OF APATOSAURUS, WITH SPECIAL REFERENCE TO SPECIMENS IN THE CARNEGIE MUSEUM.

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INTRODUCTION

The Carnegie Museum enjoys the distinction of having the most extensive collection of sauropodous dinosaur remains ever assembled. In number of articulated skeletons, and general excellence of their preservation, the collection is unrivaled. The bringing together of such a collection of fossil vertebrates entails the expenditure of a considerable sum of money, and also a vast amount of energy, skill, and perseverance on the part of those to whom the work is entrusted, whether they be curators, preparators or collectors. The above observation applies to all fossil collections, but is particularly applicable to the present assemblage of dinosaurian skeletons composed as it is of the largest of all land vertebrates.

Several specimens of this collection have formed the basis of important monographic studies, contributing greatly to our knowledge of these huge reptiles; many more still remain in storage in the cases as they were received from the field.

It is the plan of the Director, Dr. A. Avinoff, to make this huge collection available to scientific and kindred institutions as expeditiously as can be arranged. First, by a well conceived series of monographic studies; second, by the exchange of duplicate specimens. In putting this plan into execution, Dr. Avinoff has invited me to make a study of an unusually perfect skeleton of *Apatosaurus.* This specimen was collected in 1909 and 1910 by parties working under the direction of the late Earl Douglass in the Dinosaur National Monument in northeastern Utah, and it was mounted for the exhibition series in 1913. It was the subject of preliminary study by the late Dr. William J. Holland,[1] who in a short paper designated it the type of the new species *Apatosaurus louisæ* named in honor of Mrs. Andrew Carnegie. It had long been Dr. Holland's intention to use this specimen as the basis for a memoir on the genus *Apatosaurus* and before death intervened, he had all of the bones of the skeleton illustrated, comprising some four hundred pen and ink drawings. All of these illustrations were made by the well known paleontological artist, Mr. Sydney Prentice, which accounts for the artistic merit as well as for the accuracy of the illustrations which adorn this paper.

At this time I wish to express my sincere appreciation to the members of the Paleontological Staff of the Carnegie Museum for the many courtesies extended me during the course of this investigation, and especially do I wish to acknowledge my great obligations to Dr. A. Avinoff, Director of the Carnegie Museum, for the opportunity given me to study these interesting specimens as well as his ever ready coöperation in all matters pertaining to the preparation and publication of this extended study.

[1]Holland, W. J., Annals of the Carnegie Museum, vol. X, Art. 10, 1915, pp. 143-145.

THE DINOSAUR NATIONAL MONUMENT

The Dinosaur National Monument located in northeastern Utah, in the Uinta Basin some five and a half miles north of the little town of Jensen, see fig. 2, is one of the most remarkable dinosaur fossil deposits ever found. Since the specimen forming the basis of the present paper was in a way responsible for its exploration and development, it seems peculiarly appropriate at this time to give here a complete account of the operations carried on there.

The history of the Dinosaur National Monument, which was first designated the "Carnegie Museum Dinosaur Quarry," had its beginning in 1909 with the discovery of the *Apatosaurus louisæ* skeleton by Mr. Earl Douglass of the Carnegie Museum staff. Acting on a suggestion made by the late O. A. Peterson, who as early as 1892, while collecting fossils for the American Museum of Natural History, had found some fragmentary dinosaurian bones in the vicinity of Jensen on Green River, Mr. Douglass left the Eocene in the Uinta Basin where he had been collecting mammals and proceeded to explore exposures of the nearby Morrison formation. Although at first much discouraged, on August 19, 1909, at an elevation of about 5,000 feet above sea level, he discovered an articulated series of caudal vertebræ embedded in a sandstone ledge, see Pl. XXI, fig. 1. Returning on September 1st with a force of men, the excavation of the vertebræ was commenced. This specimen designated by the quarry number, "No. 1," turned out to be a very complete skeleton, and in excavating it other specimens were encountered, one after another, and thus the work continued for thirteen years. Although the deposit was not exhausted, work was discontinued here by the Carnegie Museum on December 31, 1922.

In the early work permits were secured from year to year from the Secretary of the Interior to carry on the explorations. Some years later, however, as Holland[2] observes: "To avoid being made to pay tribute to some adventurer, who might see fit to file a claim to the barren acres upon which we were carrying on our work, I instructed Douglass to file a claim under the existing laws." The decision that "fossil bones" mentioned by Douglass in his application were not mineral, the request for title to the land was disallowed. On October 4, 1915, however, under a law known as "An Act for the Preservation of American Antiquities," President Wilson, by presidential proclamation, set aside an area of 80 acres to be known as the Dinosaur National Monument and placed it under the jurisdiction of the National Park Service.

In the thirteen consecutive years that collecting was carried on here by Car-

[2] Holland, W. J., Memoirs of the Carnegie Museum, vol. IX, no. 1, p. 383, 1922.

negie Museum parties, a great mass of materials, some 700,000 pounds in all, was shipped to the Museum in Pittsburgh. In these collections were articulated skeletons of both large and small dinosaurs, and especially important was the recovery of a considerable number of well preserved skulls, the rarest and most sought-for part of the dinosaurian skeleton. The diversity of forms represented, the perfectness of their preservation and their great abundance, marks this as one of the richest deposits of Morrison fossils ever discovered.

In order to preserve all of the evidence of the original association of the skeletons and scattered bones, which later might be of assistance in assembling disarticulated parts when the specimens should be prepared in the Museum laboratory, Douglass had a quarry map prepared, see Pl. XXIII, on which all specimens as they were uncovered, were plotted. In order to insure the accuracy of the map, the quarry was marked out in four foot squares, see Pl. XXI, fig. 2, and whatever bones were found within the limits of one of these squares was sketched in a corresponding square on the quarry map, reduced to a scale of one-half inch to the foot. The map resulting, see Pl. XXIII, was largely the work of Mr. J. LeRoy Kay, assistant to Douglass, and he is to be highly complimented in having successfully accomplished so difficult an assignment. The quarry map here reproduced for the first time presents an accurate picture of the relative relationships of the skeletons and skeletal parts as they were originally found in the sandstone. Some of the skeletons are essentially complete, but more frequently only portions were found such as a tail, a section of the back, a neck, or a complete limb or foot.

A study of the quarry map shows the skeletons and bones to be grouped in large clusters, with intervals between, where fossils are sparse and few articulated parts are found. This appears to indicate that once a large carcass had stranded it formed a barrier to the current causing a diversion of the stream, which in passing around cut new channels and further scattered and disarticulated any skeletal parts encountered. The change in direction of the long bones on the outer margins of these clusters indicates the course of the currents. It is very evident that the main current of the stream ran from west to east. The long tails of the Sauropod dinosaurs, like streaming water plants in a river, have a similar down stream, eastward course. Furthermore, when parts of a skeleton are found detached and shifted out of position they have in most instances been found to the eastward of the main portion of the skeleton.

The character of the sediments indicates that apparently this represents the area of a series of old river bars, which in their shallow waters arrested the more or less decomposed carcasses, collected from many points upstream, perhaps during freshets. Thus were brought together here the animals of a whole region, a fact

which vastly enhances the interest of this great deposit. The final part of the story necessitates a rapid covering of the stranded carcasses by sand and other river sediments in order that the bones of the skeletons should become fixed in their relative positions before decomposition of the ligamentary attachments allowed them to shift out of position. That many of the larger skeletons were not completely covered immediately is shown by the fact that while the bones of the lower side remain undisturbed, those of the upper often show much displacement of parts. The strong cross-bedding of the sandstones, and the assorting of the coarse and fine materials of which the sandstones are composed give further evidence of the currents that swirled and eddied around these stranded carcasses.

In this quarry a veritable "Noah's Ark" of the animals of the Morrison period has been found. Here were skeletons of the largest of the giant Sauropodous dinosaurs, closely intermingled with remains of the smaller but powerful flesh-eating forms, and those of the slow heavily armored *Stegosaurus,* as well as the smallest and most bird-like dinosaurs.

Intermingled with these are an occasional turtle shell of the genus *Glyptops,* crocodile remains, fresh water shells, cycads, and fossil leaves, and wood fragments.

The complete faunal list of the Dinosaur National Monument Quarry, as known at the present time, is as follows:

Dinosauria

- Saurischia
  - *Apatosaurus louisæ* Holland
  - *Barosaurus* sp.
  - *Camarasaurus lentus* (Marsh)
  - *Camarasaurus* sp.
  - *Diplodocus longus* Marsh
  - *Pleurocoelus* sp.
  - *Uintasaurus douglassi* Holland
  - *Antrodemus* (*Allosaurus*) sp.
- Ornithischia
  - *Camptosaurus medius* Marsh
  - *Dryosaurus altus* Marsh
  - *Laosaurus gracilis* Marsh
  - *Stegosaurus* sp.
- Crocodilmorphi
  - *Goniopholis* sp.

Chelonia
Glyptops utahensis Gilmore
Phytosauromorphi
Hoplosuchus kayi Gilmore

During the thirteen years that the Carnegie Museum parties explored this deposit for fossils, the work, from first to last, was under the direction of Mr. Earl Douglass. In that period he was assisted by the men whose names follow, all of whom at that time were residents of the state of Utah: Joseph Ainge, Earl Douglass, J. A. Kay, J. LeRoy Kay, J. T. Kay, Clarence Nielson, Francis Schuler, William Schafermeyer, R. C. Thorne, E. M. York, Golden York.

To bring the history of the Dinosaur National Monument up to the present, mention should be made of the work done there by the U. S. National Museum and the University of Utah following its abandonment by the Carnegie Museum. In the final work of the Carnegie Museum collectors, two articulated sauropod dinosaur skeletons were partially uncovered. This fact was communicated to the officials of the Smithsonian Institution by the late director of the Carnegie Museum, Dr. Douglas Stewart, and steps were immediately taken to resume work here in order to secure a mountable skeleton of one of these huge reptiles for the National collection. It was my privilege to be placed in charge of the operations.

Arriving at the quarry about the middle of May 1923, a preliminary survey showed that of the two skeletons partially exposed in relief, the one bearing the field designation "No. 355," a *Diplodocus*, although lacking the neck, appeared to offer the best basis for an exhibition skeleton.

At that time it seemed to be beautifully supplemented by a second specimen, field No. 340, having an articulated cervical series, part of which had already been taken out by the Carnegie Museum collectors, and which later was generously turned over to the National Museum by Director Stewart. Later, preparation in the laboratory showed this neck to pertain to the genus *Barosaurus* and it could therefore not be used to replace the missing *Diplodocus* neck.

Regular work in the quarry was begun in the latter part of May and proceeded continuously up to August 8, in which time all of the *Diplodocus* specimen and such parts of the second individual as were needed were collected and shipped to Washington, D. C. Some 52,000 pounds of fossil bones and matrix were collected. Since then, the specimen has been prepared and mounted and it now forms one of the prominent exhibits in the hall of vertebrate paleontology of the United States National Museum.

Almost immediately after the cessation of work by the National Museum

collectors, the University of Utah commenced the excavation of the remaining part of the *Barosaurus* skeleton, a task successfully accomplished under the direction of Mr. Earl Douglass. A second well-preserved skeleton of *Antrodemus* (*Allosaurus*) was also collected for that Institution.

No collecting has since been done there, although a project planned by the National Park Service is to develop a permanent exhibit of the fossils *in situ*. It is proposed to clear off a considerable area of the fossil-bearing sandstone and chisel the contained fossils out in bold relief, over which will be erected a suitable building for their protection and thus develop here a unique exhibition typical of the monument. Nowhere else do the natural conditions permit of so realistic a display of dinosaurian remains in their original environment. The steep tilting of the fossil-bearing strata and the abundance of articulated skeletons are both features assuring the success of the undertaking. It is anticipated that when finished it will form one of the outstanding points of interest to those tourists who visit our National Parks.

GEOLOGY OF THE DINOSAUR NATIONAL MONUMENT QUARRY.

The principal dinosaur-bearing layer is a heavy, greenish, conglomeratic, cross-bedded sandstone that occurs in the upper half of the Morrison formation. The whole geological section, see fig. 1, beginning with the Palæozoic and extending upward successively through the Triassic, marine Sundance, Morrison, Dakota?, Aspen shale, and Frontier formations is steeply tilted with a dip of 60° to the south. Although dinosaur bones have been found at other levels, nowhere are they so abundant or so well preserved as in the ten-foot sandstone mentioned above. The outcropping ledge formed by this layer of fossil-bearing sandstone,

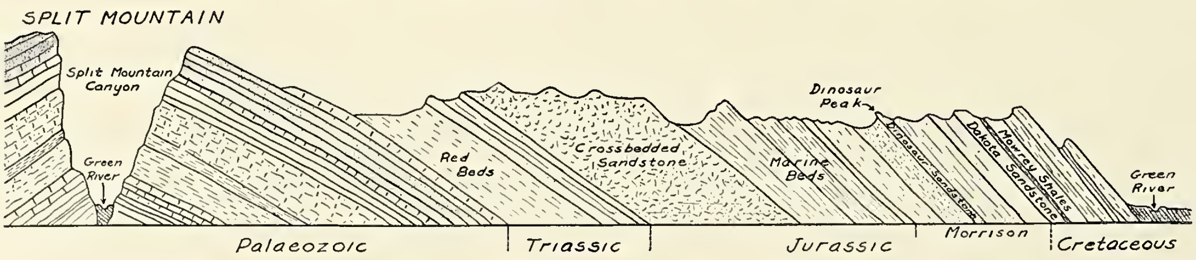

Fig. 1. Geological section near Dinosaur National Monument, Uinta County, Utah.

which weathers brown, can be easily traced for considerable distances both east and west of the hogback where the quarry is located and fossil remains are evident almost everywhere.

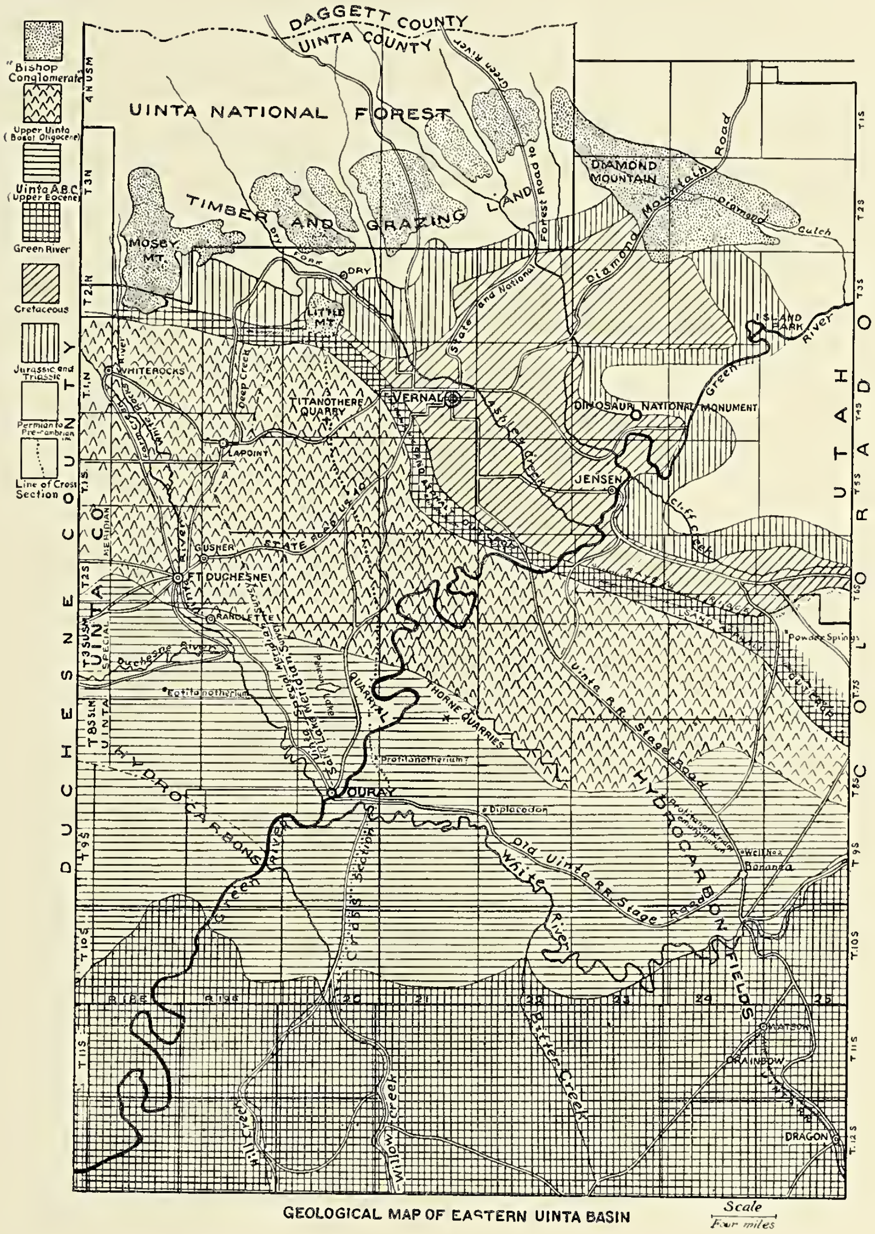

FIG. 2. Geologic map, showing the geology and geographic location of the Dinosaur National Monument. After Peterson and Kay.

The Morrison in this locality is composed lithologically of alternating beds of sandstones and shales of varying thicknesses, the whole formation in this section having a total thickness of 795 feet. The following section was measured by Dr. John B. Reeside, Jr.,[3] in 1922 in the neighborhood of the quarry.

[3]Reeside, J. B., Jr., Prof. Paper 132-C, U. S. Geol. Surv., 1923, p. 44.

Section Measured at Dinosaur National Monument Quarry

		Feet
CRETACEOUS	River-terrace materials, underlain by Hilliard shale	...
	Frontier formation:	
	Sandstone, fairly coarse, gray to brown, cross-bedded	22
	Shale, yellow, sandy, with thin layers of gray sandstone	158
	Aspen shale:	
	Shale, bluish-gray, contains many fish scales	50
	Shale, yellowish, sandy	37
	Dakota? sandstone:	
	Sandstone, gray to brown, locally weathering pink, conglomeratic, cross-bedded	35
	Shale, rusty brown and drab	27
	Sandstone, gray to brown, in thin beds	10
	Shale, rusty brown and drab	37
	Sandstone, ripple-marked, brown to gray, cross-bedded	37
JURASSIC	Morrison formation:	
	Shale, gray, violet and greenish, with lenses of greenish argillaceous sandstone, grit, and conglomerate, that weather to a chocolate-brown; highly variable unit	279
	Sandstone, greenish, conglomeratic; weathers brown. Horizon of dinosaur quarry	10
	Shales and sandstone, variegated; like second unit above	506
	Sundance formation:	
	Sandstone, fine grained, fissle, beautifully ripple-marked and rain-pitted, greenish-gray, with interbedded shale. Some layers contain *Ostrea* sp.	40
	Sandstone, platy, ripple-marked, gray, fine grained; contains *Rhynchonella gnathophora* Meek, and *Tancredia warrenana* M. & H.	2
	Shale, greenish-gray, with some platy sandstone, same color	65
	Sandstone, brown, limy, contains *Ostrea strigilecula*	1
	Shale, dark gray, almost black, containing dense blue limestone in concretions	42
	Limestone, gray, coarse, sandy, contains *Eumicrotia curta* (Hall), *Ostrea strigilecula* White, *Camptonectes platessiformis* White, *Astarte pachardi* White, *Tancredia? inornata* Meck and Hayden, *Tancredia* sp., *Dosiniajurassica* Whitfield?, *Cardioceras russelli* Reeside, *Cardioceras hyatti* Reeside, *Cardioceras cordiformis* Meek and Hayden, *Cardioceras* aff. *C. wyomingense* Reeside, *Cardioceras* sp.	1
	Shale, greenish-gray, with limestone in nodules and containing *Ostrea strigilecula* White, *Eumicrotis curta* Hall	27
TRIASSIC	Nugget sandstone of authors:	
	Sandstone, massive, cross-bedded, yellow to gray	91
	Shale, and platy sandstone, yellow to gray	12
	Sandstone, massive, gray to yellow, cross-bedded	120
	Shale, variegated, gray to brick red	107
	Sandstone, very massive, yellow to gray, forms here an impassable ridge, must be some hundreds of feet thick.	

POSITION OF THE *APATOSAURUS LOUISÆ* SKELETON IN THE QUARRY

Specimen No. 3018 C. M. in its present articulated condition, is a remarkably complete Sauropod skeleton, but when found in the quarry it was in much disarray, as shown in fig. 3. The vertebral column, which is completely preserved from the atlas to the sixty-fourth caudal vertebra was found separated into three main segments, with a further disarrangement of the distal caudals as shown in fig. 3. The complete cervical series of fifteen vertebræ was turned backward above the articulated dorsal section, the anterior members lying under the articulated pelvis. The dorsal segment had been turned over and lay on its left side, shifted some three or four feet out of line with the sacrum and the articulated caudal series. Excepting the first dorsal, which had become disarticulated and lay on its anterior face, all the others were articulated by their zygapophyses. The sacrum with the attached ilia, pubes, and ischia, formed a continuous articulated series as far back as the twenty-sixth caudal. From this point, posteriorly, there were intervals of disarrangement, but the more or less continuous line of vertebræ of diminishing size leaves no doubt of their having pertained to a single individual. When assembled for mounting, the gradation in size was so regular as to indicate a continuous series and they have been so arranged in the mounted skeleton.

The right femur was not articulated in the acetabulum as mistakenly stated by Doctor Holland,[4] but as shown by the original quarry map, it, with the tibia, fibula, and astragalus, lay in the interspace between the cervical and dorsal segments.

The articulated left fore limb and foot had been shifted to the east and south of the main mass of the skeleton. Of the right fore limb only the humerus, scapula, and coracoid were recovered. These bones were widely scattered as shown in the accompanying diagram. The left hind foot was found in an isolated position considerably above the cervical series. None of the eighteen thoracic ribs recovered were found articulated but were intimately intermingled with the other parts of the skeleton as shown in fig. 3.

The accompanying diagram has been re-drawn from the original quarry map made at the time of collecting the specimen with some refinements added as the contents of the blocks of matrix were revealed by the preparators in the laboratory. Since all surrounding skeletons and miscellaneous bones have been omitted, it gives a clearer conception of the skeleton as it was originally found.

It was the finding of the articulated caudals (11 to 20) protruding from the

[4]Holland, W. J., Annals Carnegie Museum, vol. X, Art. X, 1915, p. 1.

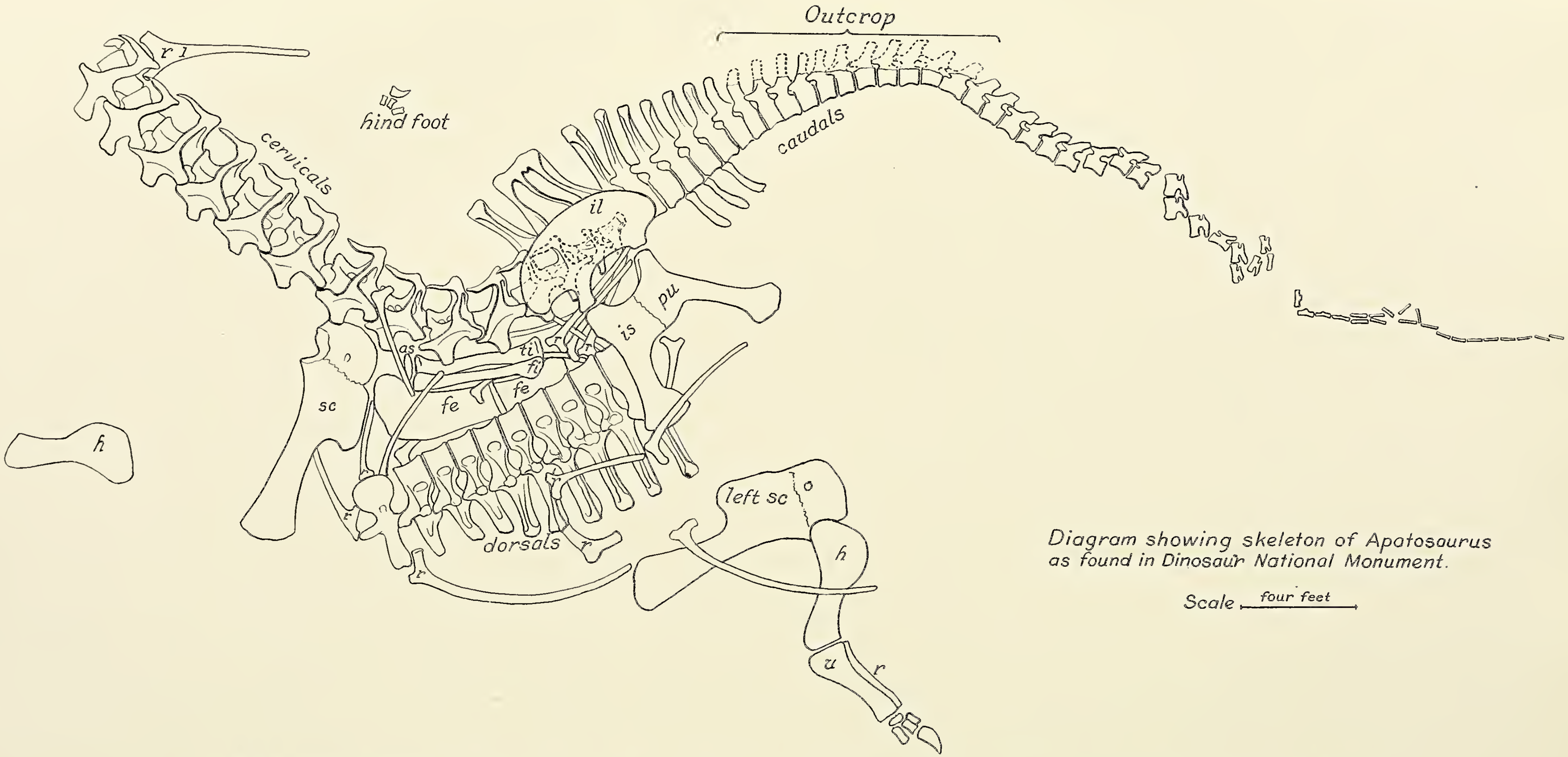

Fig. 3. Diagram showing the relationships of the various parts of the skeleton of *Apatosaurus louisæ* Holland as found in the sandstone. *As*, astragalus; *fe*, femur; *fi*, fibula; *h*, humerus; *il*, ilium; *is*, ischium; *r*, ribs; *r1*, first dorsal rib; *r*, ribs and radius; *sc*, scapula; *ti*, tibia; *u*, ulna; *outcrop*, indicates the portion that was protruding from the rock, and which led to its discovery.

ledge of rock which led to the development of this unrivaled deposit of fossils. The initial discovery is clearly shown in Pl. XXI, fig. 1, reproduced from a photograph taken at the time by Mr. Earl Douglass.

A detailed list of the skeletal parts recovered is as follows: 15 cervicals, 10 dorsals, 5 sacral and 64 caudal vertebræ; 20 cervical ribs; 18 thoracic ribs; 3 anterior chevrons; both ilia; both pubes; both ischia; right femur, tibia, fibula, and astragalus; left pes, lacking metatarsal V and phalangial 3 of digit II, 2 of digit III, and all of digit V; left scapula, coracoid, humerus, ulna, radius, scapho-lunar, and manus. The latter lacks proximal phalangials of digits III, IV, and V. The right fore limb is represented by the scapula, coracoid, and humerus. The sternal bones were not recovered.

DETAILED DESCRIPTION OF THE SKELETON OF *APATOSAURUS LOUISÆ* HOLLAND.

Apatosaurus louisæ Holland, W. J., Ann. Carnegie Museum, X, 1915, pp. 143-145; Ann. Carnegie Museum, XV, 1924, p. 120, fig. 2; Mem. Carnegie Museum, IX, 1924, pp. 383, 386; Eastman, C. R., Amer. Year Book (1916) 1917, p. 656; Science (*n.s.*) 1917, p. 119; Gilmore, C. W., Mem. Carnegie Museum, X, 1925, p. 367; Proc. U. S. National Museum, 81, No. 2941, 1932, p. 6; Hay, O. P., Carnegie Instit. Wash., Pub. 390, II, 1929, p. 195; Huene, F. v., Eclogæ Geol. Helvetiæ, XX, 1927, p. 465; Monog. zur. Geol. und Paleont. Leipsig, Ser. I, IV, 1932, p. 288; Moodie, R. L., Palæopathology, University Press, 1923, p. 192, Pl. XXIX; Mook, C. C., Ann. N. Y. Acad. Sci., XVII, 1916, p. 140.

Type: No. 3018, C. M., consists of a fairly complete skeleton. Collected by Earl Douglass and party, 1909-1910.

Locality: Dinosaur National Monument, Uinta County, Utah.

Horizon: Morrison (Beckwith), Upper Jurassic.

The Skull.

Although the genus *Apatosaurus* (*Brontosaurus*) was among the first of the Sauropodous Dinosauria to be discovered in North America, in the more than half a century that has elapsed no definite information has been obtained, and doubt still exists as to the nature of the skull this animal possessed. During this period at least a score of more or less complete skeletons have been discovered, but in no instance has a skull been found in such association that it can be positively assigned to that genus.

For more than twenty years the mounted skeleton of *Apatosaurus louisæ* in the Carnegie Museum stood headless because of this lack of information. In a

paper[5] published in 1915, Dr. William J. Holland discussed this whole matter in considerable detail but without reaching any definite conclusion. The basis of his discussion rested upon two large skulls in the Carnegie Museum collection from the Dinosaur National Monument, both of which were found considerably removed from the *Apatosaurus* skeleton. Through a mistaken understanding he was led to say: "With this skeleton [No. 3018 C. M.] lying about twelve feet from the atlas, and in the same layer, was a skull the condyle of which shows perfect adaptation to the atlas." In this he was in error for Mr. J. LeRoy Kay, who was Douglass' assistant at the time these skulls were collected and who was largely responsible for the preparation of the quarry map shown in Pl. XXIII, informs me that this large Diplodocid-like skull, No. 11162 C. M., came from the western end of the quarry nearly 100 feet distant from the nearest bones of the *Apatosaurus* skeleton and in the lowermost part of the bone-bearing stratum. Likewise the second skull, No. 12020 C. M., discussed by Doctor Holland was found somewhat farther away, but higher up in the fossil-bearing strata at practically the same level as the *Apatosaurus* skeleton. These observations by Mr. Kay have been verified from the original records, so that the question of near proximity as an argument for the association of either of these skulls with the skeleton no longer obtains. The undoubted Diplodocid affinities of skull No. 11162 C. M., though it is larger than any *Diplodocus* cranium previously known, is sufficient in my estimation to exclude it from further consideration in this connection.

The second skull discussed by Doctor Holland, No. 12020 C. M. (see fig. 4), however, has the peculiar spoon-shaped dentition originally attributed to *Brontosaurus* by Professor Marsh, and its large size, and massiveness of structure appears in keeping with the general make-up of the *Apatosaurus* skeleton. That *Apatosaurus* had teeth of the kind mentioned is apparently indicated by the finding of a single tooth[6] of this character with the large *Apatosaurus* (*Brontosaurus*) skeleton now mounted in the American Museum of Natural History. This was an isolated specimen, that is, there was no mixture of other animal bones in the ground with this specimen and thus the inference would be that all of the elements including the tooth were of a single individual.

Careful study was made of the second incomplete skull (No. 12020 C. M.) discussed by Holland, in the hope it might be used to complete the mounted skele-

[5]Annals of Carnegie Museum, vol. IX, 1915, pp. 273-277.

[6]Recent correspondence with Dr. Walter Granger informs me that neither he nor Mr. Peter Kaisen, who assisted in the collecting of this specimen, has any recollection of the finding of a tooth but in a later conversation with Prof. R. S. Lull, who also assisted with this specimen, the latter assured me that he clearly remembers finding a spoon-shaped tooth in the quarry, and that he gave it to Dr. W. D. Matthew, but that the tooth was not seen afterward.

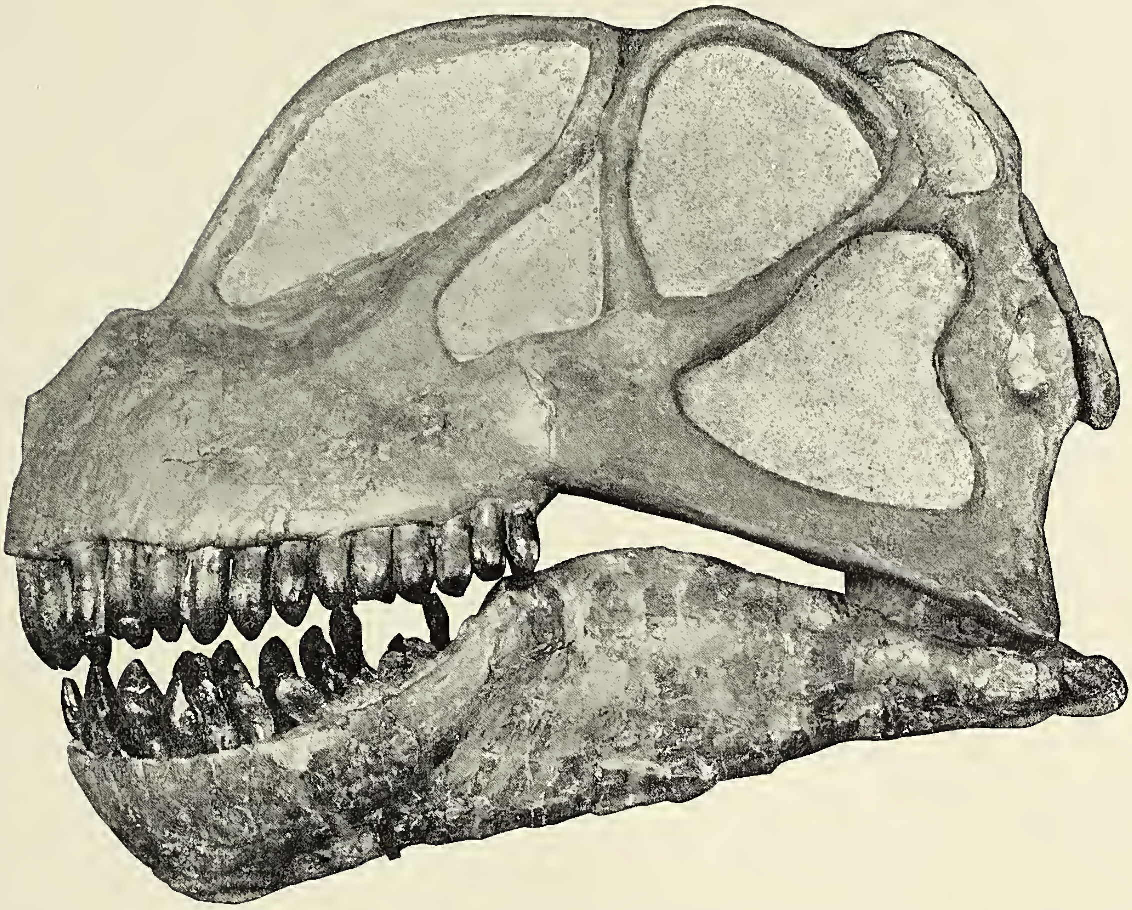

FIG. 4. Sauropod skull and lower jaws, No. 12020 C. M., a cast of which has been used to complete the mounted skeleton of *Apatosaurus louisæ*. About one-fifth natural size.

ton of *Apatosaurus louisæ,* but I was unable to satisfactorily distinguish it from the cranium of *Camarasaurus,* of which the Carnegie Museum possesses two smaller but beautifully preserved examples. Positive identification of this specimen was rendered difficult because of its incompleteness, as practically all of the top above the maxillaries is missing. Furthermore, when the skull came into my hands all of the original parts had been incorporated in a complete skull restoration, fig. 4, and thus all except the external surfaces of the bones were hidden from view. Practically all of the sutures were coalesced, and the bones surfaces are only fairly well preserved. It should also be mentioned that this skull was found in the quarry, see Pl. XXIII, intermingled with the scattered bones of a large *Camarasaurus,* No. 11393 C. M., and it might very well pertain to the same individual among whose skeletal parts it was found.

Although the large size and massiveness of this skull are in keeping with the general structure of the *Apatosaurus* skeleton, for the reasons discussed above it

was decided not to use the original skull to complete the skeleton but to substitute a replica, a temporary expedient to be used until such time as future discoveries shall disclose the true nature of the *Apatosaurus* cranium. It is the outline of this specimen that has been used to complete the restoration of the skeleton as shown in Pl. XXXIV.

In the first restoration[7] of the famous *Brontosaurus excelsus* skeleton made under the direction of Professor Marsh, the incomplete skull attributed to it is said by Lull[8] to have been found in Wyoming, near Como Bluffs, at a locality approximately four miles distant from the spot where the remainder of Marsh's type of *Brontosaurus excelsus* was obtained. In the emended restoration[9] of this skeleton, however, another skull was introduced slightly more complete than the first one used. This cranium corresponds in practically all details with a partial skull (No. 5730 U. S. N. M.) in the U. S. National Museum collection which came from the well known "Felch Quarry" near Canyon City, Colorado, and of which Marsh had made a natural size drawing of the reconstructed skull. This drawing was never published except on the skeleton. This specimen was disassociated when found and thus there is no evidence as to its original affiliations. Furthermore, except for its very large size, I can find no characteristics that will definitely distinguish it from *Camarasaurus*.

After a review of all of the various skull parts that have been attributed to the genus *Apatosaurus*, it becomes quite evident that not in a single instance has there been such an association that we can definitely say this is a skull or a portion of a skull of *Apatosaurus*. At the present time we must therefore consider the skull of *Apatosaurus* as unknown.

Vertebral Column.

The complete vertebral column of *Apatosaurus* as shown by specimens in the Carnegie Museum, and first announced by the late Dr. William J. Holland,[10] has the following formula: Cervicals 15; dorsals 10; sacrals 5; caudals 82. The formula as stated may now be considered as positively determined for the genus *Apatosaurus*. The caudal series, however, may be found to vary in total number with the individual, even within a species.

Measurements made of the segments of the vertebral column in the mounted skeleton (No. 3018 C. M.), between perpendiculars, reveal the following interest-

[7] Marsh, O. C., Amer. Jour. Sci., vol. 26, 1883, Pl. I.

[8] Holland, W. J., Ann. Carnegie Museum, vol. IX, 1915, p. 275.

[9] Marsh, O. C., Dinosaurs of North America, Pl. XLII, 1896.

[10] Holland, W. J., Amer. Nat., Vol. LVII, 1923, pp. 477-480.

ing proportions: Cervical region, including the restored skull, 21 feet; dorsal, 8 feet, 7½ inches; sacral, 5 feet, 1 inch; and caudal, 36 feet, 9½ inches; a total length of 71 feet, 6 inches, between perpendiculars.

The backbone of *Apatosaurus* is characterized by the massiveness of the individual vertebræ; the absence of true pleurocoels in the caudals; and especially the stout heavy character of the cervical ribs.

As in other members of the Sauropoda, *Apatosaurus* has pleurocentral cavities in all of the presacrals, and paired spines in the postero-cervical and antero-dorsal regions.

The nomenclature used in the description of the various laminæ and cavities is in the main that first proposed by Osborn.

CERVICAL VERTEBRÆ.

The fifteen cervical vertebræ preserved in the specimen were found in series. There was some distortion due to the compression to which they had been subjected, but this has been largely corrected during preparation. Cervicals thirteen, fourteen, and fifteen, however, were so badly crushed that it was thought best to replace them in the mounted skeleton by plaster restorations of these vertebræ. They are, however, sufficiently well preserved so that most of their important characteristics can be determined. In the present paper the illustrations of these bones were skilfully reconstructed by Mr. Prentice in order to make them more readily available for comparison with the other elements of the neck. Cervical ribs were present in all except C 1, C 2, C 3, C 14, and C 15. It is especially unfortunate that these posterior ribs are not well preserved as this transition from cervical to thoracic ribs is perhaps the least known portion of the Sauropod skeleton. The *Apatosaurus* cervicals are much stouter than those of *Barosaurus* and *Diplodocus* and differ from those of *Haplocanthosaurus* in having divided spines. In general they approach those of *Camarasaurus* more closely than any other Sauropodous dinosaur with which we are acquainted at this time.

The Atlas.—The atlas of specimen No. 3018 C. M. is completely preserved and is coössified with the axis, as shown in fig. 6. So close is the union of the centra of these two vertebræ that all trace of their junction has been obliterated except on the ventral surface, where the atlas intercentrum has a length of 54 mm. The odontoid was probably present but its recognition is no longer possible because of coalescence with the intercentrum. Due to this fact the intercentrum and odontoid when viewed from the front appear to be a solid block-like bone slightly wider than high with a moderately cupped face for articulation with the occipital condyle of the skull, see fig. 5. The neurapophysial processes are also fused with the intercentrum,

but their expanded ends probably contribute to the formation of the condylar cup as in other Sauropoda. Above this end the neurapophyses are constricted, but as they extend upward they rapidly expand into wide, comparatively thin processes that curve inward to cover and furnish protection to the spinal cord as it passes from the skull to the axis. The paired neuropophyses do not meet on the median line, but are separated a few millimeters at about the middle of their length.

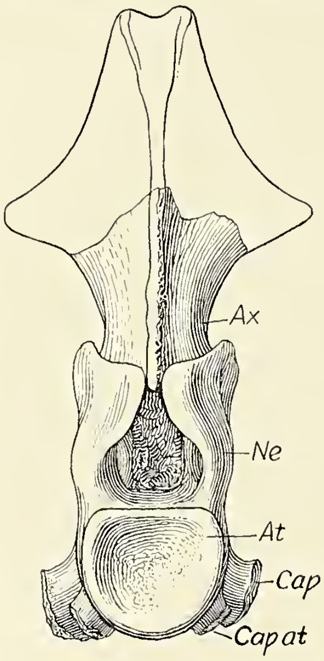

Fig. 5. Coalesced atlas and axis of *Apatosaurus louisæ*. Type. No. 3018 C. M. Viewed diagonally from the front. *At.*, atlas; *Ax.*, axis; *Cap.*, capitular facet for articulation of cervical rib for axis; *Cap. at.*, capitular facet for cervical rib of atlas; *Ne.*, neuropophysis. One-fourth natural size.

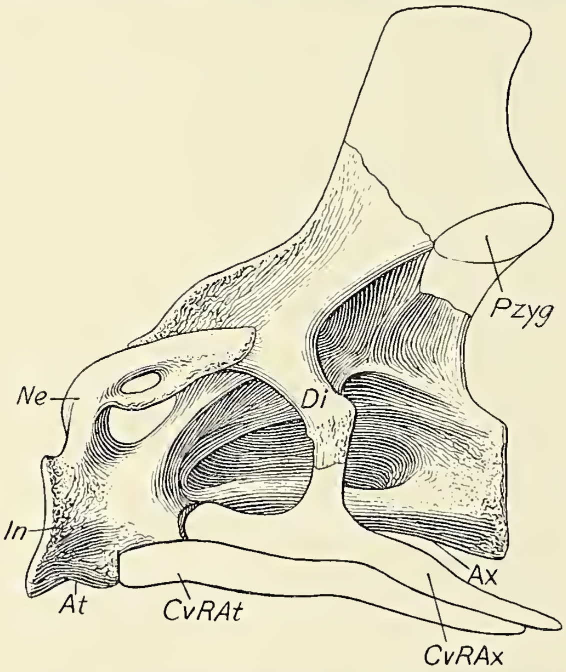

Fig. 6. Coalesced atlas and axis of *Apatosaurus louisæ*. Type. No. 3018 C. M. Lateral view. *At.*, atlas; *Ax.*, axis; *Cv.R.At.*, cervical rib of atlas; *Cv.R.Ax.*, cervical rib of axis; *Di.*, diapophysis; *In.*, intercentrum; *Ne.*, neuropophyses; *Pzyg.*, postzygapophyses. One-fourth natural size.

Anterior and posterior to this point of near-median contact, their inner borders are strongly divergent as shown in fig. 5. The expanded process of the right neuropophyses is perforated by a sub-ovate opening, possibly the result of an old injury. The ventral surface of the intercentrum posteriorly is transversely hollowed out, on either side of which strong facets are developed for the articulation of the single-headed cervical rib.

MEASUREMENTS OF ATLAS

Width of atlas intercentrum	70 mm.
Height of atlas intercentrum	64 mm.
Length of atlas intercentrum on ventral surface	54 mm.

The Axis.—The axis is quite perfectly preserved except for the missing postzy-

gapophyses and top of the neural spine. The centrum is coalesced with the intercentrum of the atlas, a condition not before observed in a member of the Sauropoda. The centrum is strongly opisthocoelus as is the case in all of the succeeding cervicals. There is a deep pleurocentral cavity on either side that extends forward into the base of the odontoid process. Viewed from below, the centrum is greatly constricted at mid-length, with expanded ends, more especially the anterior. The ventral surface of the anterior end is concave transversely being widened on either side by the development of heavy capitular processes for the articulation of the cervical ribs which are missing. The articular face of this process looks outward and strongly backward. Posterior to this process a deep longitudinal groove further lightens the side of the centrum, it disappears at about the middle length of the bone. The posterior blade of the horizontal lamina extends from the transverse process towards the posterior zygapophyses as in *Diplodocus*. A prominent transverse process springs from the middle of the sides of the arch. It is moderately broad and is directed downward, backward and outward and terminates in an enlarged articular end. The infradiapophysial lamina has an oblique position and gives support to the posteriorly directed transverse process in becoming a short laminar buttress connecting the process with the side of the neural arch and separating the infradiapophysial from the postdiapophysial cavity. The top of the neural arch is pinched together into a rounded median ridge that rises rapidly toward the spine, which is missing. Anteriorly this crest separates the two halves of the neurapophyses of the articulated atlas. The principal characters of the axis are well shown in fig. 6.

Cervicals three to twelve.—The cervical centra gradually increase in length from the first to the eleventh which is the longest of the series. In breadth and height there is a progressive increase from the first to the fifteenth. In form, the cervicals most nearly resemble those of *Camarasaurus* but have taller spinous processes and shorter and more robust cervical ribs.

The centra of the entire series are strongly opisthocoelus, the anterior balls being practically hemispherical in the forward half of the series and becoming transversely subelliptical in the posterior half. The walls of the centra appear to be of moderate thickness and the pleurocoelia are relatively small. The lateral walls of the centra slope upward and inward while the infrapostdiapophysial laminæ project outward more or less horizontally on the hinder halves of the centra. The latter therefore roof over shallow asymmetrical depressions which Osborn and Mook call *external pleurocoelia*. From these depressions smaller but deeper cavities extend into the bodies of the centra. The number and shape of these cavities are variable, there are usually two but often three. The anterior one in

every case excavates the proximal portion of the parapophyses. Where there are three it appears that the posterior one is divided by a thin bar or accessory lamina. All of the cervical pleurocoels are relatively smaller than in other American Sauropod genera of equivalent age. Occasionally the anterior pleurocoele is divided. Inferiorly the centra are concave in both directions.

The neural arches of all of these vertebræ are comparatively low. Laterally they are crossed by anterior and posterior diapophysial lamina which separate off infraprezygapophysial, infradiapophysial, and infrapostzygapophysial cavities. The infraprezygapophysial cavity is situated above the anterior portion of the centrum and is bounded above by the horizontal lamina and below by the infraprediapophysial lamina. Posterior to C. 7, this cavity is bisected by an accessory lamina that extends upward and backward to unite with the horizontal lamina and cuts off a small accessory pocket that lies principally beneath the diapophyses. The infradiapophysial cavity is situated below the diapophyses, and is bounded in front and back by the anterior and posterior branches of the infradiapophysial laminæ. The infrapostzygapophysial cavity lies above the posterior half of the centrum and is bounded above by the horizontal lamina and below by the posterior branch of the infradiapophysial lamina. They lie almost entirely behind the diapophyses.

The diapophyses, short and slender on the vertebræ of the anterior portion of the neck, progressively increase in length and in massiveness posteriorly. They project outward and downward in all of these vertebræ. The diapophyses in the anterior cervicals are situated rather far forward, but in the remaining cervicals this process is given off at about midlength, see B, Pl. XXIV. They are braced by the horizontal laminæ above and below by the anterior and posterior branches of infradiapophysial laminæ.

The parapophyses are strongly developed throughout the series. They are situated on the infero-lateral borders of the centra immediately posterior to the ball, and extend obliquely downward and outward, ending well below the ventral surface of the centrum. All are fully coössified with the capitulum of the cervical rib, an enlargement of the bone marking the point of their coalescence. Their superior surfaces merge into the walls of the centra and are excavated by a cavity, which may or may not be a subdivision of the pleurocoels of the centrum.

The prezygapophyses of all the vertebræ posterior to the axis are wide apart. Their articular surfaces look upward and inward. The prezygapophyses are braced from below by the infraprezygapophysial lamina, above by the slender supraprezygapophysial lamina; posteriorly by the horizontal lamina, and internally by the intraprezygapophysial lamina.

Viewed from the front, above the neural canal and below the intraprezygapophysial lamina are a pair of small cavities, separated on the median line by short, oblique laminæ which unite on the median line and give support to the interprezygapophysial lamina.

The postzygapophyses are slightly higher and somewhat farther apart than the prezygapophyses. Their articular surfaces look downward and slightly outward. They are braced from above by the suprapostzygapophysial laminæ, anteriorly by horizontal laminæ, and inferiorly by infrapostzygapophysial laminæ. Infraprezygapophysial laminæ form the lower lateral boundaries of the neural canal, but commencing with C. 9 there are two small infraprezygapophysial cavities between the top of the canal and the intraprezygapophysial lamina. These cavities are separated by a short vertical lamina that braces the intraprezygapophysial lamina on the midline.

The spines as in *Camarasaurus* are situated over the posterior half of the centrum as far posteriorly as C. 7. From this point posteriorly the cervicals have the tops of the spines above the center of the centra. Unfortunately the type of *A. louisæ* lacks most of the spine tops, only those of cervicals eight, ten, and twelve being complete; thus the point of change from single to bifid spines cannot be determined in this specimen. In specimen No. 563, C. M., identified by Hatcher as pertaining to *Brontosaurus*, an identification with which I concur, there are nine cervical vertebræ preserved, three of which I regard as cervicals, three, four, and five. These show the spines to be single as far posteriorly as the fifth vertebra. Since C. 7 shows a well defined notch between the metapophyses, it seems to be a fair conclusion that C. 6 in *Apatosaurus* is the first vertebra to show a notch on the summit of the spine.

In *Camarasaurus supremus* Osborn and Mook[11] make the observation that, "In C. 5, the spine has a very slight median notch." In *C. lentus*,[12] however, the first notched spine is that of C. 7. From C. 6 to C. 9 inclusive, the spinal notch increases steadily in depth. From C. 9 to C. 15 inclusive, the spine is completely divided into two metapophyses.

Throughout, the spines are braced anteriorly by long supraprezygapophysial laminæ, and posteriorly by shorter suprapostzygapophysial laminæ. C. 2 to C. 5 are characterized by deep postspinal cavities below and behind the spines and between the postzygapophyses. Posterior to C. 5, they gradually reduce in size to C. 9, where the cavity has practically disappeared. C. 8, C. 10, and C 12, show the

[11]Osborn and Mook, Mem. Amer. Mus. Nat. Hist., n.s., III, Pt. 3, 1921, p. 294.

[12]Gilmore, C. W., Mem. Carnegie Museum, X, No. 3, 1925, p. 369.

tops of the metapophyses to be bluntly truncated with a slight overhang of the anterior border. None show any transverse thickening of this end.

Beginning with C. 10 at the center between the bases of the metapophyses, there is a prominent rugose knob-like projection that extends backward and doubtless served as the attachment of one of the powerful intervertebral muscles, see 10, Pl. XXIV. This feature probably persists throughout the remainder of the cervical series, but due to the crushing of the posterior members this assumption cannot be certainly verified.

MEASUREMENTS OF CERVICALS

Vertebra No.	Greatest length of centrum		Greatest diameter centrum posterior end		Greatest breadth across transverse processes		Greatest height at center	
	C. M. No. 3018	C. M. No. 563	C. M. No. 3018	C. M. No. 563	C. M. No. 3018	C. M. No. 563	C. M. No. 3018	C. M. No. 563
	mm.	mm.	mm.	mm.	mm.	mm.	mm.	mm.
1	45	...	...	...	...	...	125	...
2	190	...	85	...	150c	...	...	...
3	280	250	100	80	190c	185	...	315
4	370	300	100	125	355	280	...	360
5	...	342	...	134	...	315	...	380
6	440	...	150	...	430	...	...	...
7	450	415	190	170	485	425	...	...
8	485	415	225	205	545	480	560	...
9	510	445	230	215	635	520	...	560
10	530	475	250	250	750	640	...	...
11	550	...	240	...	675	...	825	...
12	490	...	265	...	770	...	815	...
13	480	...	...	...	684c	...	...	...

c = estimated.

DORSAL VERTEBRÆ.

The complete dorsal series of ten vertebræ are present in specimen No. 3018 C. M. All except the first articulated by their zygapophyses are shown in Fig. 3. The dorsals of *Apatosaurus* are distinguished by giving support to free ribs, instead of the coalesced or fixed ribs of the cervical region. There are no lumbars. The transition from cervical to dorsal is gradual except for the change in rib support, but more rapid than in *Diplodocus*. In the mounted skeleton only the centrum of D. 10 remains though in all probability all of this bone was originally present as shown in the quarry diagram, see fig. 3.

The First Dorsal.—The first dorsal in *Apatosaurus louisæ* is distinguished from all others by the small size of the pleuro-central cavity situated at mid-height and entirely on the posterior half of the centrum, and by the capitular facet developed

at mid-height on the centrum toward the anterior end. The centrum is strongly opisthocoelus and from the end is broadly ovate in outline. The paired neural spines or metapophyses, viewed laterally, are relatively narrow antero-posteriorly and there is no indication of a median spine such as Hatcher mentions on the first dorsal of *Diplodocus*. The neural arch is noticeably higher than in the posterior cervicals. The anterior and posterior zygapophyses are both somewhat more elevated than the diapophyses and are supported by the anterior and posterior blades of the horizontal laminæ. The ends of both transverse processes are missing in this vertebra. They are supported from below by the short, rather slender inferior diapophysial lamina, which runs obliquely downward and forward to unite with the superior branch of the prezygapophysial lamina. An oblique, infradiapophysial lamina runs downward and backward from the diapophyses uniting with the neural arch near the top of the centrum. The pre- and supradiapophysial cavities are deep and well enclosed. The postdiapophysial cavity is shallow but clearly outlined. Viewed from the front, this vertebra appears low with greatly expanded transverse processes and zygapophyses. The neural spine is deeply bifurcated. Viewed from the front, the spines are broad at the base tapering rapidly to a slender extremity that from a side view has a slightly expanded truncate end, see Pl. XXV. The large anterior zygapophyses are joined by an intrazygapophysial lamina having the appearance of a sagging shelf. Inferiorly the zygapophyses are supported by robust infraprezygapophysial lamina. The infraprezygapophysial cavity is deep, and at the center divided by a heavy vertical lamina that arises immediately above the neural canal and extends upward to unite with the transverse lamina that joins the zygapophyses.

The suprapostzygapophysial lamina directed upward and outward form the posterior border of the spine. The infrapostzygapophysial laminæ are pillar-like. The supra- and infrapostzygapophysial cavities are of moderate depth.

Dorsals two and three.—Compared with D. 1, the second and third dorsals may be distinguished at once by the successive elevation of the capitular facets, and a progressive increase in the size of the pleurocentral cavities. In D. 2, the capitular facet is on the side of the centrum at a level with its top; in D. 3, it occupies a position on the side of the arch about midway between the top of the centrum and the top of the prezygapophyses. In the type of *Apatosaurus excelsus* and in the Field Museum *Apatosaurus* specimen this condition is found on D. 4. Both centra are opisthocoelus, the ball much less prominently developed on D. 3. Both centra are broadly sub-ovate in outline. The diapophyses are stout, the ends being obliquely terminated by the tubercular facets for the ribs. They are supported from below by the greatly expanded infradiapophysial laminæ, which reach their

strongest development in D. 2. From this vertebra posteriorly they gradually narrow dorso-ventrally. The diapophyses of both of these vertebræ extend outward and slightly downward below the horizontal. The spines or metapophyses as they are designated by Marsh are paired, and there is no indication of an incipient median spine as found by Hatcher[13] in *Diplodocus*. In D. 2, the notch between the metapophyses is wide and deep, but in D. 3, this notch is much narrowed, and somewhat shallower in depth. The articular surfaces of the postzygapophyses have assumed a more elevated position on D. 2, probably in anticipation of the development of the hyposphene-hypantrum method of articulation found for the first time on D. 3, see C, Pl. XXV. In D. 2, the postzygapophyses are supported by a pair of pillar-like infrapostzygapophysial laminæ that arise from the arch, slightly above its junction with the centrum. In D. 3, however, these laminæ are much reduced in size and, instead of being parallel as in the preceding vertebra, converge to meet where they join the hyposphene, and to which they give support. The infrahyposphenal cavity is bisected by a slender lamina that runs from the bottom of the hyposphene to the top of the neural canal. The articular surfaces of the pre- and postzygapophyses are wide apart but the postzygapophyses of D. 3 are closely joined, a feature that continues throughout the rest of the dorsal series. This wide spacing of the zygapophyses is a cervical feature that has been carried over into the dorsal segment. The anterior divided spines have practically the same laminar bracings as the single spines which succeed them. They are supported anteriorly by supraprezygapophysial laminæ, posteriorly by suprapostzygapophysial laminæ, and laterally by supradiapophysial laminæ. These laminæ extend obliquely upward and forward from the posterior sides of the diapophyses to the rugose summits of the spines. Thus they separate the anterior and posterior supradiapophysial cavities from each other. On D. 3, the supraprezygapophysial laminæ pass obliquely downward from the top of the spines and join one another on the midline where they meet the transverse shelf that joins the two zygapophyses. At their junction a small incipient upward projection apparently marks the beginning of the prespinal lamina, which is well developed in the next dorsal posteriorly. At the center and on the posterior side of the lamina joining the two metapophyses of D. 2, is a rugosely developed projection that evidently marks the point of attachment of an important inter-vertebral ligament. In the next posterior dorsal this space is occupied by a short postspinal lamina. On the left side this lamina is buttressed by two short, oblique accessory laminæ, an example of asymmetry noted in many of these vertebræ, as they have been in the vertebræ of other members of the Sauropoda.

[13]Hatcher, J. B., Mem. Carnegie Museum, vol. I, no. 1, 1901, p. 26.

Dorsals four to ten.—The centra of these vertebræ gradually shorten in a posterior direction. All are opisthocoelus, but the convexity is slight and confined entirely to the upper half of the centrum much as in *Diplodocus*, a feature that distinguishes these vertebræ from those of *Camarasaurus* which have well developed anterior balls throughout this portion of the vertebral column. Pleurocentral cavities are present in the entire dorsal series. Posterior to the third these are subequal in size and extend slightly into the base of the neural arch. The posterior ones are located nearer the anterior than the posterior borders. They are relatively smaller than in *Diplodocus* and *Barosaurus*. Neural arches are of moderate height. They consist, at the anterior borders principally, of the infraprezygapophysial laminæ. These rise from the top of the centrum and are pillar-like in appearance. A single infradiapophysial lamina separates the infraprezygapophysial and infrapostzygapophysial cavities on the sides of the arches, in dorsals 4 to 8 inclusive. In D. 9, it is intersected by a short diagonal accessory branch rising from below on the side of the arch and forming a small infradiapophysial cavity. The infraprezygapophysial and infrapostzygapophysial cavities are bounded above by the horizontal laminæ. The infradiapophysial laminæ arise from the side of the arch well above the level of the centrum. The arches are much restricted fore and aft as well as transversely, never wider than the middle of the centrum. The parapophyses which bear the capitular rib facets are moderately well developed. On dorsals 4 to 8 inclusive, they are on a level with the prezygapophyses, but on D. 9, they drop to a point below the lower level of the prezygapophyses. They are supported principally by the infraprezygapophysial lamina. They comprise part of the thick mass of bone which is made up of the prezygapophyses and of the hypantra. The capitular facets face obliquely outward and downward, and slightly forward. These facets vary considerably in size, but become smaller posteriorly, see Pl. XXV. The pedicels become progressively longer in a posterior direction.

The diapophyses are long and extend outward at right angles to the perpendicular axes of the vertebræ, except in D. 9, which has an appreciable upward inflection above the horizontal. The diapophyses are supported from above by the supradiapophysial laminæ, anteriorly and posteriorly by the horizontal laminæ, and below by the infradiapophysial laminæ. The tubercular facets face directly outward in all of the dorsals posterior to the fifth. In dorsals 4 and 5 they all look outward and downward.

The prezygapophyses are large throughout the dorsal series. In the anterior dorsals they are steeply inclined toward the median line, a condition that continues subequal as far back as D. 8. On the ninth, however, the prezygapophyses reach a nearly horizontal position. It is quite evident that the missing prezygapo-

physes of the tenth dorsal would be horizontal, as indicated by the horizontal position of the postzygapophyses of D. 9, see Pl. XXV.

The postzygapophyses are equal in size and in inclination to the prezygapophyses described above. They are supported from below, where they join on the median line by the bases of the hyposphene.

The hyposphene-hypantrum articulation is present on all of the dorsal vertebræ beginning with the third. The hyposphenes extend downward from the point on the midline where the postzygapophyses join.

Immediately below the zygapophyses the hyposphenes are narrow transversely, but below this narrow part they rapidly expand into a diamond-shaped process that is braced from below by a single vertical lamina that fades out on the median posterior face of the arch about half way between the hyposphene and the neural canal. Each hyposphene has two articular faces on its exterior and superior surfaces. These faces are continuous with the postzygapophyses. They look outward on the constricted portion, and upward and outward on the expanded part. The hyposphene reaches its strongest development on D. 4, and progressively decreases in size posteriorly. Dorsal 4 is the first to show a hypantrum. Each hypantrum consists of a pair of articular surfaces located below the prezygapophyses. The hypantral surfaces are continuous with the postzygapophyses and face obliquely downward and inward, nearly at right angles to the prezygapophyses. When articulated the hyposphene fits in between and under the hypantra thus giving strong support to the zygapophyses in locking the vertebræ together. This form of articulation of the vertebræ makes a very rigid backbone, as there is little chance for movement except in an antero-posterior direction.

The spines of the dorsal vertebræ gradually increase in height from front to back. In D. 4, the spine is wide, transversely and moderately notched; in D. 5, the spine is much narrowed with a notch slightly less deep. In D. 6, the notch is shallow, and D. 7 shows no indication of a notch. In *Diplodocus* this notch is present on the spine of D. 9, and *Camarasaurus* shows only a slight indication of it on the spine of D. 7. The spines are elongate as a whole in the posterior half of the dorsal series. Those behind D. 6 have the spines forming more than one half the total height. The laminæ bracings consist of supraprezygapophysial laminæ in front and suprapostzygapophysial laminæ behind. The former are supported laterally by short supradiapophysial laminæ.

These laminæ as far posterior as D. 5, are distinct and continue upward to the top of the spine, but on D. 6, they merge with the suprapostzygapophysial to form a single wide lamina when viewed from the side. This lamina narrows antero-posteriorly on the succeeding dorsals except for the expanded top as far posterior

as D. 8. On the ninth the supradiapophysial branch disappears. On the middle line of both front and back sides of the spine are pre- and postspinal laminæ, the posterior usually being more robust than the anterior. These run the full length of the spine with a tendency to bifurcate at the bottom where they unite with the pre- and postzygapophyses. These laminæ separate subequal elongate depressions on either side, especially on the upper half of the spines. None of these laminæ extend to the summit but all merge into the rugose head.

All of the tenth dorsal is missing above the centrum, and for that reason has not been illustrated with the other dorsal vertebræ on Pl. XXV.

Among the unpublished plates of *A*. (*Brontosaurus*) *excelsus* (Marsh) prepared for Professor O. C. Marsh by the U. S. Geological Survey are excellent illustrations of the third, fourth, fifth, and eighth dorsal vertebræ. These have been critically compared with the corresponding vertebræ of *Apatosaurus louisæ* and some interesting differences of structure are found, the most important being the fact that D. 4 in *A. excelsus* in its structural features is equivalent to D. 3 in *A. louisæ*. It is the first vertebra to develop a hyposphene; the capitular facet is on the side of the arch about midway between the centrum and the prezygapophyses, and the centrum has a well developed ball. Since practically these same conditions occur in the Field Museum *Apatosaurus* specimen with the exception of a ball on the centrum, it may indicate that in *A. excelsus* we have an advanced structural specialization or cervicalization of the anterior dorsals not found in *A. louisæ*.

COMPARATIVE MEASUREMENTS OF DORSAL VERTEBRÆ

Vertebra No.	Greatest length of Centrum			Greatest diameter centrum posterior end			Greatest height of vertebra above middle of inferior border		
	C. M. No. 3018	C. M. No. 563	F. M. No. 7163	C. M. No. 3018	C. M. No. 563	F. M. No. 7163	C. M. No. 3018	C. M. No. 563	F. M. No. 7163
	mm.	mm.	mm.	mm.	mm.	mm.	mm.	mm.	mm.
1	310	345	370	355	335	400	845	...	490
2	315	285	360	355	365	410	850	855	530
3	310	280	330	350	330	410	885	869	580
4	260	213	290	315	345	400	995	915	720
5	260	235	290	335	315	410	1060	...	880
6	270	260	280	335	305	400	1060	...	1060
7	260	235	260	335	335	410	1275c	...	1200
8	275	225	300	350	340	410	1340c	...	1290
9	255	230	250	315	355	410	1350	...	1310
10	240	...	250	365	...	400	...	...	1340

c = estimated.

SACRAL VERTEBRÆ

There are five coössified vertebræ in the sacrum of *Apatosaurus louisæ*, No. 3018 C. M. All of these vertebræ function as sacrals, although in this specimen,

as it has been shown in practically all adult members of the Sauropoda, the primary sacrum consists of the three median vertebræ. These are augmented by a vertebra in front, a sacrodorsal, and by a vertebra at the back, a sacrocaudal. This feature of the Sauropod skeleton has been thoroughly discussed by Riggs,[14] Hatcher,[15] and Osborn and Mook[16] and there appears no necessity of discussing this question at this time.

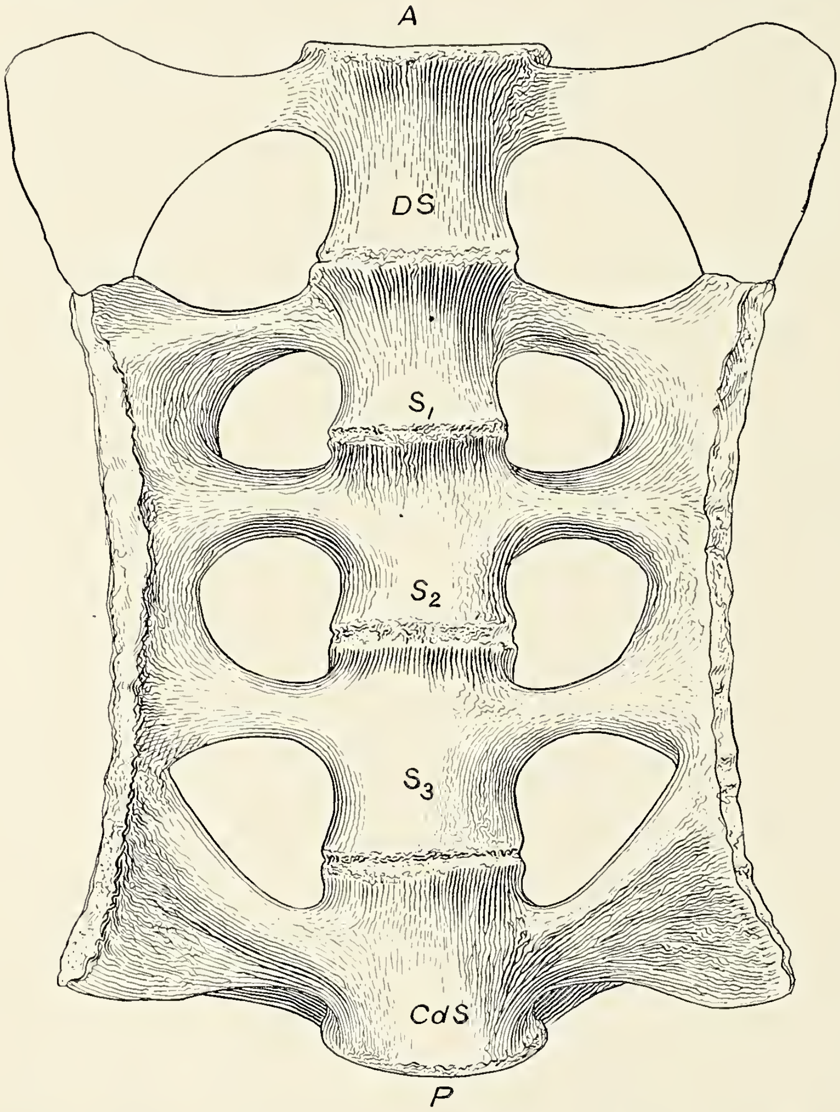

FIG. 7. Sacral vertebræ of *Apatosaurus louisæ*. Type. No. 3018 C. M. Ventral view. *A.*, anterior end; *Cd-S.*, caudo-sacral; *D-S.*, dorso-sacral; *P.*, Posterior end; S_1, S_2, S_3, primary sacrals, one, two, and three. One-tenth natural size.

[14] Riggs, E. S., Field Columbian Museum, Pub. 82, II, Geol. Ser., No. 4, 1903, pp. 180-186.

[15] Hatcher, J. B., Memoirs Carnegie Museum, I, 1901, No. 1, pp. 30-34; Ibid. II, 1903, No. 1, pp. 14-18.

[16] Osborn, H. F., and Mook, C. C., Memoirs American Museum Natural History, III, 1921, Pt. III, pp. 309-316.

In the restored condition of the present sacrum the ventral side is practically all that is visible for examination. The spinous processes and diapophyses are all restored. That these parts were originally present appears to be indicated by the fact they were sketched in on the quarry map, and in all probability have since been destroyed through the vicissitudes of collecting and preparation.

A ventral view of the coössified sacral centra is shown in fig. 7. These vertebræ have a combined length of about 1325 mm., divided between the five elements as follows: D-S, 275 mm.; S_1, 225 mm.; S_2, 260 mm.; S_3, 295 mm.; Cd-S, 275 mm. The inferior surfaces of the centra are broadly rounded. In this view the sides of the centra are much less constricted than in either the dorsals which precede, or the caudals that succeed them. The sacral ribs are all fully coalesced with the centra, and except in the caudosacral, which unites centrally, the others arise from the antero-lateral surfaces of the centra. In *Apatosaurus excelsus*[17] as shown in the type, and in the Field Museum specimen[18] the first two ribs arise from the mid-lateral surfaces on the centra. The outer ends of the sacral ribs are much expanded and completely fused with one another into a horizontal plate or bar that gives support to the ilium on either side. They enclose four sacral cavities on each side. The shafts of these ribs are more slender than in *A. excelsus* and their proximal ends are much less expanded than in that species, excepting S_5, all of the centra articulate with the ribs on their anterior halves; whereas in *A. excelsus* they attach the full length of the centra.

Viewed from the side, see fig. 19, the articular faces of the first and last sacral are not parallel but lean toward one another at the top, a condition found in other Sauropod sacra. This feature, when the vertebræ are properly articulated, causes the column to arch slightly upward both forward and back of the sacrum and brings about a lizard-like posture to this part of the vertebral column. Unfortunately in most of the mounted Sauropod skeletons, the articulation of these bones has been modified, as in the present instance, by preconceived ideas and the true curves of the column at these points have been lost.

CAUDAL VERTEBRÆ.

In addition to the articulated caudal series of 64 vertebræ pertaining to the type of *Apatosaurus louisæ*, No. 3018 C. M., there was available for this study two other specimens of *Apatosaurus* in the Carnegie Museum collection having good series of caudal vertebræ. The first, No. 3378 C. M., is a complete, articulated vertebral column, of which 82 vertebræ constitute the caudal region. This is the

[17]Marsh, O. C., Dinosaurs of North America, Pl. XXIII, 1896.

[18]Riggs, E. S., Field Columbian Museum, Pub. 82, Geol. Ser. II, No. 4, 1904, Pt. I, p. 179.

only complete, articulated vertebral column of *Apatosaurus* known at this time. The specimen is a considerably smaller individual than the type, but comes from the same quarry, see Pl. XXIII, Field No. 160. The second specimen, No. 563 C. M., from Sheep Creek, Albany County, Wyoming, is also slightly smaller than the type of *Apatosaurus louisæ*. With this disarticulated skeleton there were 18 caudal vertebræ representing practically all parts of the tail except the whip-lash portion. This specimen was identified by Hatcher[19] as pertaining to *Brontosaurus*. A study of all three of these specimens has made it possible to determine nearly the complete structure of the tail. The outstanding feature of the *Apatosaurus* tail is its great length, especially the attenuated whip-lash portion.

The caudal series of specimen No. 3018 C. M. consists of 64 vertebræ, of which the anterior 26 were articulated by their zygapophyses with the sacrum. The remaining vertebræ were found in such relationship to the articulated parts as to leave no doubt that all pertain to this one individual. Their relative positions as found in the quarry are clearly shown in fig. 3. In the mounted skeleton these caudal vertebræ have been articulated as a continuous series and no reason has been found for not so regarding them. Their regularly graduated continuity (when allowance is made for slight distortion) appears to indicate the correctness of their arrangement.

This specimen was the first one found giving absolute information that *Apatosaurus* had a long whip-like extension of the tail such as had been previously discovered in the genus *Diplodocus*.

In completing the tail of the mounted skeleton, nine additional artificial elements were added to the tip making a total of 73 vertebræ. That the complete series is in excess of that number is now clearly shown by specimen No. 3378 C. M., see Pl. XXVIII, of which the complete series formed a part of an articulated vertebral column that extended from the atlas to the very tip of the tail. There are 82 caudal vertebræ in this series, as now numbered, although an elongated element near the tip may represent a coalesced pair in which event the total would be 83. In all probability this number varies with the individual even of the same species. There must have been great liability of loss from the tip of such a slender appendage, and the uniformity in size of these terminal rod-like caudals is such that any loss would be difficult of detection.

In 1915, Dr. Holland[20] briefly mentioned this specimen, No. 3378 C. M., of which he published an illustration of the distal portion of the series (Nos. 34 to 82) but at that time made no mention of the genus to which it pertained. I have

[19]Hatcher, J. B., Annals Carnegie Museum, vol. I, Art. 13, 1902, p. 356.

[20]Holland, W. J., Annals Carnegie Museum, vol. IX, 1915, p. 27, Pl. LIX.

compared this series with the corresponding vertebræ of the mounted skeleton and such close agreement is found as to leave no doubt of their being congeneric. Although the complete tail represents a considerably smaller animal than No. 3018 C. M., the heavy solid nature of the centra, the disappearance of the transverse processes on the fifteenth caudal, and correspondence of the points of change in the form of centra and spinous processes show the two specimens to be in close accord.

The anterior caudal vertebræ, as far posteriorly as the seventh, may be described as procœlus. The anterior faces of all these vertebræ are concave; the posterior face slightly concave on the upper fourth, but with a pronounced ball on the lower three-fourths of this end in the first caudal, as shown in Pl. XXVI. This convexity grows progressively smaller in a posterior direction, disappearing entirely on the seventh caudal vertebra. Riggs[21] notes a similar change in the anterior caudals of the Field Museum *Apatosaurus*. It thus grades into an uncertain amphicœlous type of centrum, beginning with the seventh, that persists to the thirty-fourth caudal. On the thirty-fourth a ball again appears on the posterior end. On the thirty-fifth there is a ball on both ends, and this type of articulation persists throughout the slender "whip-lash" extremity of the tail, a style of articulation that permits of the greatest mobility in all directions.

Viewed from the end the centra of the first six caudal vertebræ are considerably higher than wide, a proportion that distinguishes these vertebræ of *A. louisæ* from the homologous elements of *A.* (*Brontosaurus*) *excelsus* which are subequal in these two diameters. Likewise, as shown by the type of *A. excelsus*, and the two referred specimens, the Field Museum *Apatosaurus* and No. 563 C. M., the procœlus type of centrum begins with C. 2, instead of C. 1, as in *A. louisæ*.

The centra are relatively short antero-posteriorly as compared with *Diplodocus*, and all are constricted medially. With some slight exceptions they grow progressively shorter from first to last. Likewise, the centra become successively smaller in all other diameters as far posteriorly as the fortieth caudal, but posterior to this point the centra, except in length are rod-like and continue with slight diminution to the very tip.

The neural arch is low and massive throughout. In the type specimen, No. 3018 C. M., the arch persists as far back as C. 32, see Pl. XXVII. In specimen No. 3378 C. M., the last complete arch is found on C. 35, see Pl. XXVIII. The arches are simple, not divided by laminæ as in the cervicals and dorsals. The first fourteen caudal vertebræ posterior to the sacrum bear transverse processes, see Pl. XXVI. A similar number are present in No. 3378 C. M., whereas in the Field

[21]Riggs, E. S., Field Columbian Museum, Geol. Ser. II, No. 4, 1903, p. 189.

Museum specimen, Riggs recognized only twelve. The resoration of this specimen made under his direction shows more. He calls attention[22] to the fact that the Yale specimen, the type of *Apatosaurus excelsus* has only twelve caudals bearing transverse processes, and the American Museum specimen eleven. Since the caudal verbebræ of the latter were not found articulated, the number cited may or may not be correct. In any event the agreement among these specimens is fairly close, for the place of disappearance of such a vestigal process could hardly be expected to be constant. The transverse processes on the first caudal are largely missing, but enough remain, see Pl. XXVI, to show the great dorso-ventral expanse, and also to indicate that these wing-like processes were not perforated by foramina-like openings as in the first caudal of the type *A.* (*Brontosaurus*) *excelsus* Marsh.

These expanded wing-like transverse processes continue backward to C. 6, where they are reduced to a roughened vertical ridge. These processes spring from the side of the arch and centrum, projecting outward at right angles to the main body of the vertebræ. The upper horizontal borders are on a level with the zygapophyses, and the outer borders of the first six slope obliquely downward to about mid-depth of the centrum. Where the superior and outer borders intersect, prominent shoulders are developed which persist as far posteriorly as C. 5. Posterior to the fifth caudal, the top of the oblique outer border merges directly into the side of the neural arch. This oblique border is rugosely roughened and overhangs the vertical laminæ on both the anterior and posterior sides. On the posterior side, the surface of the transverse process is fairly smooth, but on the anterior face each process is pocketed by a pair of shallow depressions placed one above the other. On C. 3, the lower depression exists as a rounded, well defined foramina-like opening that gives entrance to the interior of the process. In *A. louisæ* none of the transverse processes is entirely perforated as found in the anterior caudals of at least two specimens of *A. excelsus.* Holland[23] cited this difference as one of the specific characters for distinguishing the two species. In all probability this feature will vary with the individual. Posterior to the sixth caudal vertebra the transverse processes or caudal ribs are simple in character, gradually decreasing in size posteriorly and finally disappearing entirely after the fourteenth caudal vertebra.

The prezygapophyses are moderately well developed but small in comparison with the size of the vertebræ. They decrease regularly in size in a posterior direction and persist as far posteriorly as the thirty-second caudal and were functional as far back as the twenty-fifth vertebra. In specimen No. 3378 C. M., nonfunc-

[22]Riggs, E. S., idem, p. 188.

[23]Holland, W. J., Annals Carnegie Museum, X, Art. 10, 1915, p. 2.

tional prezygapophyses are present on the thirty-fifth, and in this series they also articulate as far back as the twenty-eighth.

The prezygapophyses of the anterior seven are supported from below by heavy infraprezygapophysial laminæ that rise from the centrum. The articular surfaces look strongly upward and inward. They extend forward and overhang the end of the centra. Superiorly they are braced by supraprezygapophysial laminæ; these laminæ disappear at some point between the third and the eighth vertebræ. Unlike the anterior caudals in *Camarasaurus* and *Haplacanthosaurus*, additional support is given the prezygapophyses in caudals one, two, three, and four, by a short horizontal lamina running from the top of the transverse process. This lamina, however, is not present on the posterior side.

The postzygapophyses are situated at the bases and somewhat beneath the spines. Functional postzygapophyses are found as far back as the twenty-fifth vertebra, and vestigal articulations are to be observed on the thirty-second. The articular surfaces look strongly downward and outward. In the four anterior caudal vertebræ the postzygapophyses are supported at their junction by a median vertical plate that arises from the arch above the neural canal. This plate has been designated the "*intraspinous lamina*" by Osborn and Mook[24] but I am of the opinion that it represents a vestige of a hyposphenal articulation. This idea is given support, especially by the transverse expansion of this plate as shown in B, Pl. XXVI. From above, the postzygapophyses are braced by the suprapostzygapophysial laminæ.

The spinous processes are partially or wholly missing as far posteriorly as the eighth caudal in specimen No. 3018 C. M.

The first, second, and third caudals lack their upper extremities. In the illustrations, see Pl. XXVI, these missing parts have been drawn in outline from the vertebræ as restored in the mounted skeleton. When compared with the complete first caudal of *A. excelsus*, No. 563 C. M., an individual shown, by the measurements of the limb and other bones, to be of approximately the same size, it could appear that these spines as restored are somewhat too long. On the other hand the spines throughout the anterior caudal and dorsal region are more attenuated than in *A. excelsus*.

The spines of the first three caudals are composed primarily of prezygapophysial, postzygapophysial, heavy prespinal, and less well developed postspinal laminæ. These laminæ largely disappear as separate structures in the vicinity of the twelfth caudal. In the anterior caudal region, the summits are broader than their bases. From the region of caudal thirteen, posteriorly, there is little transverse expansion of the upper termination and the spines are flat and plate-like.

[24]Osborn, H. F. and Mook, C. C., Memoir Amer. Mus. Nat. Hist., N.S., III, Pt. III, 1921, p. 320.

The spines of the anterior vertebræ are relatively narrow, antero-posteriorly, but between the thirteenth and twenty-second they gradually widen. A vestigal spine is present on the thirty-second. The progressive changes in the form of the spines from front to back in *Apatosaurus* are best shown in specimen No. 3078 C. M., see Pl. XXVIII. I find no evidence of the emargination of the tops of the spines of the anterior vertebræ as in *Diplodocus*.

An interesting feature of the tail in this specimen is the coössification of caudals twenty-two and twenty-three, see fig. 8. Their condition is probably attributable to traumatic causes since there is an excess of extraneous bony matter extending over the joint comparable in a way to the diseased Sauropod caudals described and illustrated by Moodie.[25] In *Diplodocus* there are no less than three specimens known having coössification of the caudal vertebræ in practically the same region of the tail. Hatcher[26] was the first to suggest that it occurred at the point where the tail first touched the ground and for that reason was more susceptible to injury. With the dorsal elevation of the tail as it leaves the sacrum, a condition now known to prevail in most of the Sauropoda, it no longer touches the ground in this region but posterior to it, thus this explanation no longer obtains. The possible suggestion has been made that in rearing up on the hind legs this portion of the tail would be brought into use as a support and that injury might at times result from the strain to which it was subjected.

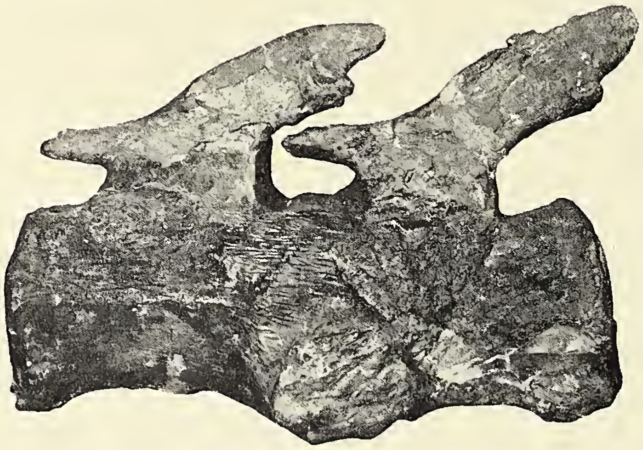

Fig. 8. Coössified caudal vertebræ (22d and 23d) of *Apatosaurus louisæ*. Type. No. 3018 C. M. Viewed from left side. About one-fifth natural size.

Moodie[27] has the following to say regarding these vertebræ: "A badly infected lesion, showing on the surface several large necrotic sinuses, indicates an injury

[25]Moodie, R. L., Amer. Jour. Sci., vol. 41, pp. 530-531, fig. 1, 1916.

[26]Hatcher, J. B., Memoirs Carnegie Museum, vol. I, no. 1, 1901, p. 37.

[27]Moodie, R. L., Paleopathology, 1923, p. 165.

to the tail of a large dinosaur *Apatosaurus louisæ*, in the Carnegie Museum. It may be an example of spondylitis deformans, though other lesions of this nature seen in the tails of dinosaurs do not possess necrotic sinuses. It may be an osteomyelites or an incipient hemangioma. A *Diplodocus* skeleton in the same museum exhibits two lesions on the tail, around which have developed a pathology similar to spondylitis deformans. The injuries in both dinosaurs are near the point where the tail reaches the ground, and it may well be that trauma is the cause of them all."

Specimen No. 3378 C. M. also shows the beginning of a coössification of the twenty-second and twenty-third caudal vertebræ, by the uniting of the spinous processes, see Pl. XXVIII.

Chevrons.

There were only three chevrons preserved with specimen No. 3018 C. M. These, however, were found articulated and thus give positive evidence that the first chevron articulates with the first caudal vertebra. Riggs found one below the first caudal in the *Apatosaurus* skeleton in the Field Museum (Field Columbian Mus., Pub. 82, vol. 2, 1903, p. 191) and on the evidence of this specimen it is now certain that all of the anterior caudals were chevron bearing. All three of the chevrons have the hæmal canal entirely closed in by a bridge of bone. The first is shorter than the second chevron, but not as short as the one figured by Riggs. The missing chevron bones on the mounted skeleton have been restored after those of the Field Museum specimen but those were found disarticulated so that their positions cannot be considered as precisely determined. The distal end of the third chevron in the present specimen is restored.

Chevron facets appear to be present as far posteriorly as the thirty-third caudal. In specimen No. 3378 C. M., there is a portion of a chevron attached to the thirtieth caudal, see Pl. XXVIII. On the restoration, Pl. XXXIV, chevrons have been restored after the above evidence.

MEASUREMENTS.

Greatest length of first chevron	360 mm.
Greatest length of second chevron	405 mm.

Ribs

All of the presacral vertebræ in *Apatosaurus* are rib bearing. The cervical ribs are stout and seldom exceed the centra in length.

Cervical ribs.—All of the cervical ribs that are present are fully ankylosed with their respective vertebræ. They are entirely missing from the atlas, axis, C. 3, C. 14, and C. 15. The tubercular processes extend outward and downward from

COMPARATIVE MEASUREMENTS OF CAUDAL VERTEBRÆ

No.	Greatest length of centrum				Transverse diameter posterior end				Greatest height over all			
	A. louisæ No. 3018 C. M.	*A. excelsus* No. 7163 Field Mus.	*A. excelsus* No. 563 C. M.	*A.* sp. No. 3378 C. M.	*A. louisæ* No. 3018 C. M.	*A. excelsus* No. 7163 F. M.	*A. excelsus* No. 563 C. M.	*A.* sp. No. 3378 C. M.	*A. louisæ* No. 3018 C. M.	*A. excelsus* No. 7163 F. M.	*A. excelsus* No. 563 C. M.	*A.* sp. No. 3378 C. M.
	mm.	mm.	mm.	mm.	mm.	mm.	mm.	mm.	mm.	mm.	mm	mm.
1	240	192	150	...	300	390	325	...	1250e	1130	1005	...
2	205	220	155	...	290	380	305	...	1120e	1010	...	...
3	215	230	160	140	280	360	295	...	1020e	920	735	...
4	190	230	160	145	280	350	270	...	920e	870	...	...
5	190	220	160	145	285	330	265	...	830e	760	...	...
6	175	210	150	...	250	310	255	...	765e	680	595	...
7	190	200	150	140	260	300	225	...	675e	630	510	...
8	185	200	150	...	245	290	215	...	625	530	495	...
9	185	200	155	155	240	290	195	165	575	530	420	...
10	190	200	...	149	240	290	...	...	530	500	...	420
11	190	190	155	150	235	280	225	165	500	520	...	368
12	200	200	...	147	220	260	...	160	475e	470	...	355
13	195	200	175	160	215	250	190	165	470	470	380	...
14	200	210	...	160	190	220	...	164	...	420	...	...
15	200	220	...	167	190	220	...	161	...	410	...	...
16	...	220	205	170	...	210	235	155	...	380	365	...
17	205	220	190	172	170	210	195	137	...	360	355	...
18	200	330	...	178	170	200	...	...	...	330	...	...
19	200	310	...	181	185	210	...	130e	...	310	...	210
20	225	300	...	183	165	190	...	112	...	300	...	...
21	210	280	...	161	150	180	...	110	...	280	245	210
22	405	270	...	174	...	170	...	...	...	270	...	210
23		250	190	170	131	170	111	109	...	250	...	200
24	195	..	...	177	145	...	...	107	...	...	...	190
25	205	...	185	168	125	...	105	90e	...	..	220	185
26	188	...	175	165	125	...	110	...	...	...	...	175
27	190	...	...	165	105	...	...	80e	...	...	...	170
28	200	...	...	150	100	...	...	80	...	...	...	155
29	180	...	...	145	86	...	...	70e	...	...	...	140
30	175	...	160	140	83	...	80	67	...	...	...	130
31	170	...	160	135e	76	...	65	60	...	...	...	...
32	163	...	...	139	69	...	...	50	...	...	...	110
33	160	...	...	132	55	...	...	40	...	...	...	85
34	153	...	...	140	48	...	...	30	...	...	...	77
35	155	...	...	122	45	...	...	30	...	...	...	50
36	152	...	...	127	44	...	...	27	...	....	...	...
37	151	...	...	110	46	...	...	20	...	...	...	50
38	145	...	...	...	38	...	...	...	...	...	...	...

39	150	...	...	...	41	...	...	...	...	...	...	...
40	148	...	...	...	37	...	...	...	...	...	...	...
41	140	...	...	120	34	...	...	18	...	...	...	...
42	143	...	...	130e	32	...	...	20	...	...	...	...
43	140	...	...	120	29	...	...	...	...	...	...	...
44	155	...	...	120	35	...	...	...	...	...	...	...
45	152	...	...	115	32	...	...	...	...	...	...	...
46	153	...	...	118	29	...	...	15	...	...	...	...
47	174	...	...	125	30	...	...	20	...	...	...	...
48	144	...	...	110	32	...	...	...	...	...	...	...
49	...	...	...	122	...	...	...	...	...	...	...	...
50	145	...	...	115	35	...	...	...	...	...	...	...
51	154	...	...	110	36	...	...	...	...	...	...	...
52	145	...	...	125	26	...	...	...	...	...	...	...
53	145	...	...	123	25	...	...	...	...	...	...	...
54	135	...	...	130	29	...	...	...	...	...	...	...
55	133	...	...	120	29	...	...	...	...	...	...	...
56	135	...	...	112	29	...	...	...	...	...	...	...
57	124	...	...	...	28	...	...	...	...	...	...	...
58	130	...	...	116	28	...	...	...	...	...	...	...
59	130	...	...	115	28	...	...	...	...	...	...	...
60	120	...	...	120	31	...	...	...	...	...	...	...
61	128	...	...	56	26	...	...	...	...	...	...	...
62	120	...	...	110	25	...	...	...	...	...	...	...
63	135	...	...	115	28	...	...	...	...	...	...	...
64	130	...	...	110	26	...	...	...	...	...	...	...
65	...	...	...	112	...	...	...	...	...	...	...	...
66	...	...	...	120	...	...	...	...	...	...	...	...
67	...	...	...	120	...	...	...	...	...	...	...	...
68	...	...	...	110	...	...	...	...	...	...	...	...
69	...	...	...	96	...	...	...	...	...	...	...	...
70	...	...	...	85	...	...	...	...	...	...	...	...
71	...	...	...	90	...	...	...	...	...	...	...	...
72	...	...	...	85e	...	...	...	...	...	...	...	...
73	...	...	...	70	...	...	...	...	...	...	...	...
74	...	...	...	60	...	...	...	...	...	...	...	...
75	...	...	...	83	...	...	...	...	...	...	...	...
76	...	...	...	85	...	...	...	...	...	...	...	...
77	...	...	...	62	...	...	...	...	...	...	...	...
78	...	...	...	55	...	...	...	...	...	...	...	...
79	...	...	...	52	...	...	...	...	...	...	...	...
80	...	...	...	85	...	...	...	...	...	...	...	...
81	...	...	...	50	...	...	...	...	...	...	...	...
82	...	...	...	42	...	...	...	...	...	...	...	...

e = estimated.

the diapophyses and in this way add considerably to the width of the neck. The capitular process is usually the stouter one of the two and it extends inward and upward to join the capitular facet of the vertebra. The shafts of the ribs extend backward parallel with the centra but well below their ventral borders. They taper rapidly to an obtuse end that seldom reaches a point beyond the posterior end of the centrum. In none of the cervical ribs of this specimen is there a forwardly projecting end as in *Diplodocus*, or as in many of the ribs of No. 563 C. M., see Pl. XXXI. There is, however, a heavy blunt projection that extends downward and slightly backward. On the inner side the shaft is hollowed out.

The stoutness of the cervical ribs of *Apatosaurus* furnish one of the outstanding characters of the genus. Their stoutness of structure at once distinguishes them from the slender cervical ribs of *Diplodocus*, and from the long attenuated ribs of *Camarasaurus* and *Barosaurus*.

Thoracic Ribs.—There are twenty thoracic ribs in *Apatosaurus*, and eighteen of these are preserved with the present skeleton. The tenth pair is missing. None of the ribs was found articulated, see fig. 3, but all are in a good state of preservation. Those of the left side correspond very closely with those of the right which are illustrated in Pl. XXIX.

The first rib differs from all of the others in having a nearly straight shaft, and in having the peduncle bearing the capitulum nearly at right angles to the main axis of the bone. From the union of the capitulum with the tuberculum the shaft diminishes very gradually to a point near the distal end. The tuberculum and capitulum are subequal in size and supported on peduncles of subequal length. The distal end is truncated. The second, third, and fourth are the stoutest of the series. The ribs increase in length from the first to the sixth which is the longest. From the sixth posteriorly they rapidly shorten, the ninth being only a little more than one half the length of the sixth. The second rib presents a broad and rather flat external surface. Near the distal end, the bone is slightly expanded, with a noticeable backward inclination. The anterior surface of the shaft below the head is perforated by a large foramen which leads to an internal cavity.

The tuberculum and capitulum, far apart in the first rib, gradually approach one another posteriorly. Beginning with the fourth, when placed in a vertical position, the capitulum projects high above the tuberculum but in a posterior direction this relationship is progressively altered until in the ninth they are nearly on the same level. No trace was found of either of the tenth pair. In the Field Museum specimen[28] the right one of the tenth pair was coössified with the vertebra, while the distal end abutted the crest of the ilium.

[28]Riggs, E. S., idem., p. 177.

From this evidence it would appear that the restored rib in the mounted skeleton had been made too long. The principal features of the ribs are clearly indicated in Pls. XXIX and XXX.

COMPARATIVE MEASUREMENTS OF RIBS

Rib No.	Length		Breadth across head and tubercle		Breadth at middle of shaft	
	C. M. No. 3018	F. M. No. 7163	C. M. No. 3018	F. M. No. 7163	C. M. No. 3018	F. M. No. 7163
	mm.	mm.	mm.	mm.	mm.	mm.
1	1475	...	475	430	90	80
2	1615	...	450	510	100	95
3	1980	...	375	500	90	130
4	2025	...	350	440	105	130
5	2060	2130	340	405	95	125
6	2075	2070	310	420	90	85
7	1820	1850	290	360	90	90
8	1665	1700	270	310	85	85
9	1140	1260	300	250	60	80
10	...	620	...	240	...	60

Pectoral Girdle.

The pectoral girdle is represented by the coalesced scapula and coracoid of both sides, but no trace was found of the sternal plates.

Scapula.—Both scapulæ and coalesced coracoids are present with this specimen, and both are in excellent preservation. Viewed from the side the outline of the scapula of *Apatosaurus louisæ* is intermediate in form between that of the type of *A.* (*Brontosaurus*) *excelsus* and the type of *Apatosaurus ajax*, as is clearly shown in fig. 10. In the straightness of the posterior border, and the slight expansion of the upper end, it is nearer to the last named species than to *A. excelsus.*

The proximal end of the scapula is broadly expanded, this breadth being about one-half the total length of the bone. From end to end it is regularly curved as in all members of the Sauropoda, see C, fig. 9.

On the external side, between the coraco-scapula suture and the spine or ridge that extends diagonally across the expanded proximal end, the surface of the bone is concave forming an area of considerable extent for muscular attachment. On the upper side of this ridge the surface slopes off gradual to the border, there being hardly any evidence of a superior fossa so prominently indicated in the *Camarasaurus* scapulæ, and to a slightly less degree in the scapula of *A. excelsus.* The superior border is somewhat thickened transversely, with a slight expansion of this

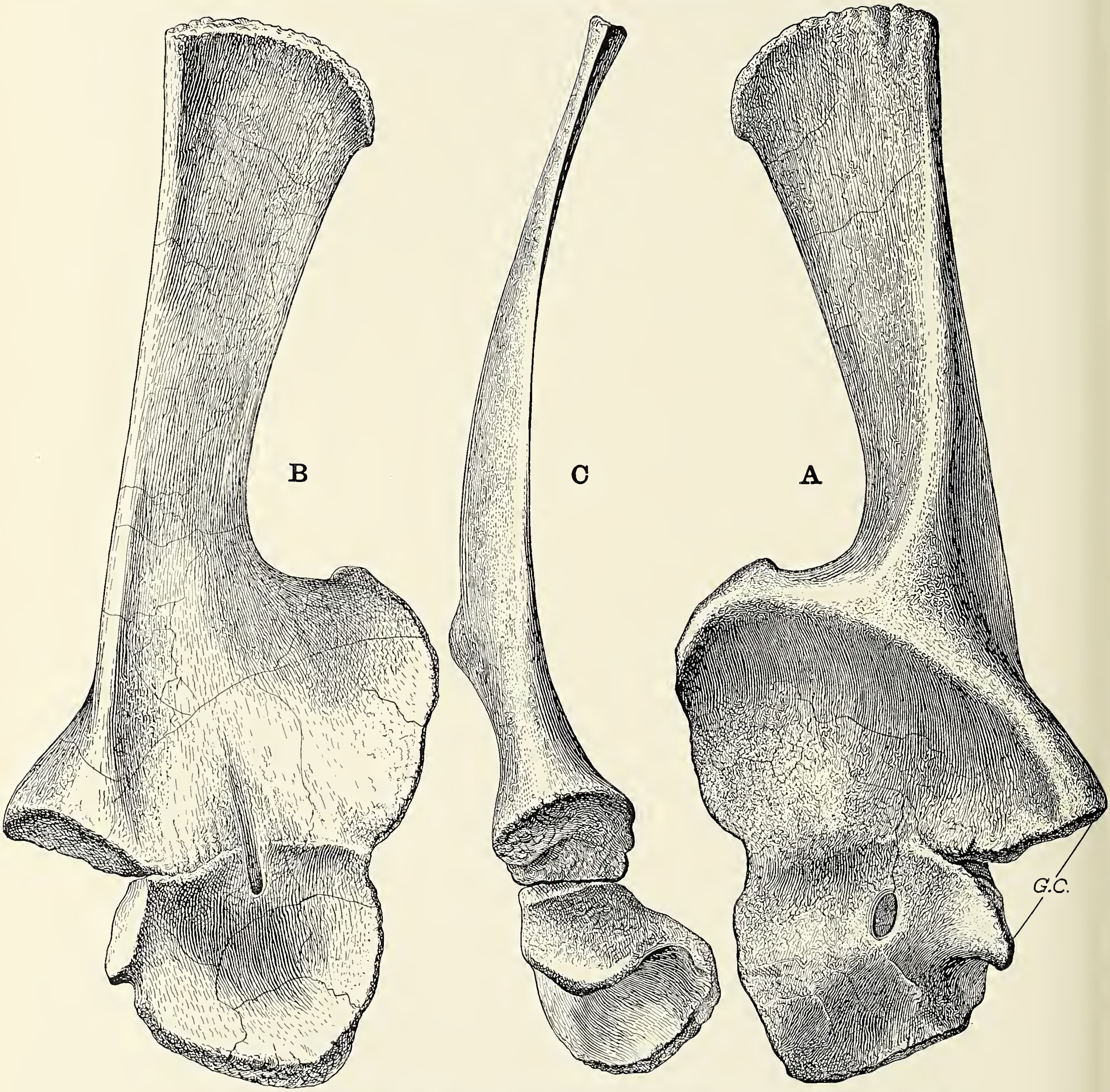

FIG. 9. Left scapula and coracoid of *Apatosaurus louisæ* Holland. Type. No. 3018 C. M. *A.*, external view; *B.*, internal view; *C.*, posterior view; *G.C.*, glenoid cavity. One-tenth natural size.

end in the anterior direction. The surface of the upper end is rugosely roughened probably for the attachment of a suprascapula. The external surface of the blade is irregularly convex, the internal slightly concave. Both anterior and posterior borders thin out to sharp edges. The sharp edge of the posterior border continues downward to the backwardly inclined portion to form the glenoid cavity near the lower end, where the bone thickens transversely, see C, fig. 9. The scapula of *A. louisæ* may be distinguished at once, by the narrowness of the distal extremity of the blade, and the straightness of its posterior border, from such forms as *Diplodocus, Haplocanthosaurus,* and *Camarasaurus,* all of which have a double expansion of this end. From *Alamosaurus* it may be separated by the relatively narrower blade and the higher and more oblique position of the transverse ridge. The straightness of the posterior border of the blade, the reduced area of the superior

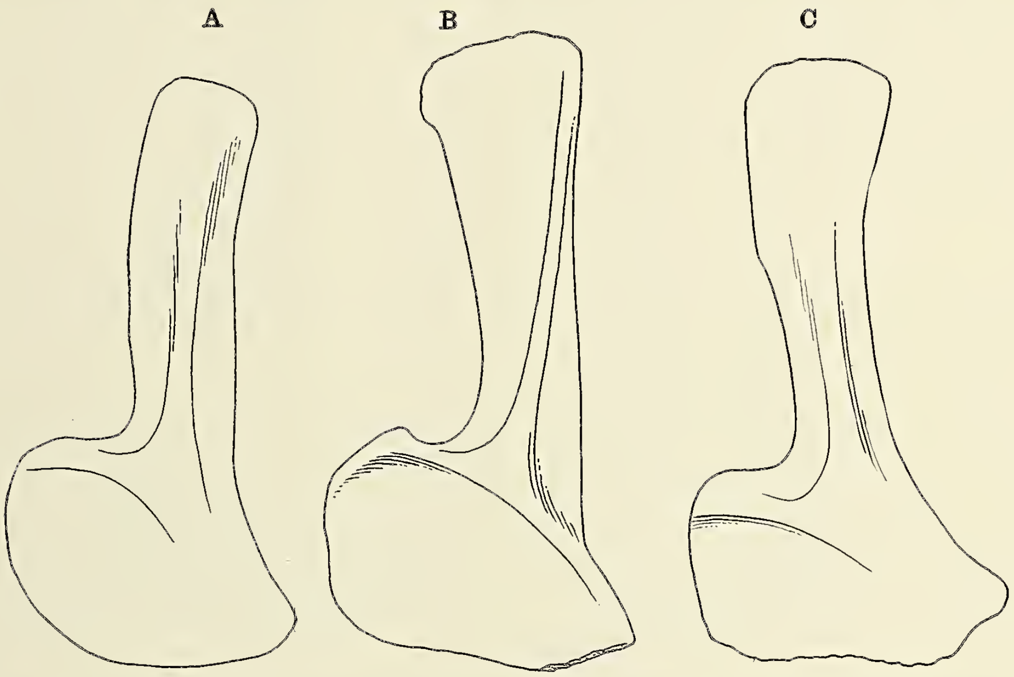

FIG. 10. Comparative outline views of *Apatosaurus* scapulæ. *A.*, left scapula of *A. ajax*, Type; *B.*, same of *A. louisæ*, Type; *C.*, same of *A. excelsus*, Type. All figures about one-twenty-fourth natural size.

muscular fossa, and the diagonal trend of the transverse ridge, are features that seem to distinguish the scapula of *A. louisæ* from that of *A. excelsus*, see fig. 10.

Coracoid.—The coracoid of *A. louisæ* is subrectangular in outline, its vertical and longitudinal diameters being subequal. The whole bone is massive, with an irregularly convex outer, and a concave inner surface. It is much thickened about the glenoid cavity. The coracoid is perforated by a large elliptical foramen that passes diagonally backward through the bone, see fig. 9, emerging on the inner

side close to the coraco-scapula suture about midway between the glenoid and anterior borders.

The anterior and inferior margins are relatively thin. Between the inferior margin of the glenoid cavity and the inferior border there is a shallow notch in the posterior border of the coracoid.

COMPARATIVE MEASUREMENTS OF SCAPULÆ AND CORACOIDS

	No. 3018 C. M.	No. 563 C. M.
	mm.	mm.
Greatest length of combined scapula and coracoid	2020	...
Greatest length of scapula	1640	1660e
Greatest breadth of scapula	820	840
Least breadth of scapula	240	265
Greatest breadth top of scapula	400	...
Length of coracoid	370	...
Greatest expanse of glenoid cavity	325	...

e = estimated.

Fore Limb.

The left fore limb was found articulated as shown in fig. 3, but of the right leg only the humerus was recovered.

Humerus.—The humerus resembles that of *Camarasaurus,* the bone being stout and heavily built. It presents a constricted shaft with expanded ends, the proximal to a much greater extent than the distal end. The deltoid ridge is prominently developed, extending along the anterior external border from the proximal end for one half its length. The anterior face of the upper half of the humerus is broadly hollowed out transversely. The proximal end is convexly rounded from side to side. The head is placed midway between the internal and external borders, but a little nearer to the former and is directed more strongly backward than in *Diplodocus.* Its surface is very rugose. The transverse diameter of the distal end is about twice that of the fore and aft diameter. Viewed from the end it is subrectangular in outline, see D, fig. 11. The articular surface is roughly rugose. On the posterior border there is a depression indicative of an anconeal fossa. There is a small, poorly defined, external condyle. The principal characters of this bone are shown in fig. 11. The distal end has a slight inclination forward. Compared with the humeri of *A. excelsus,* see fig. 33, the shaft is more robust and the deltoid ridge is less prominently developed from a proximal view. In all other respects the bones are identical.

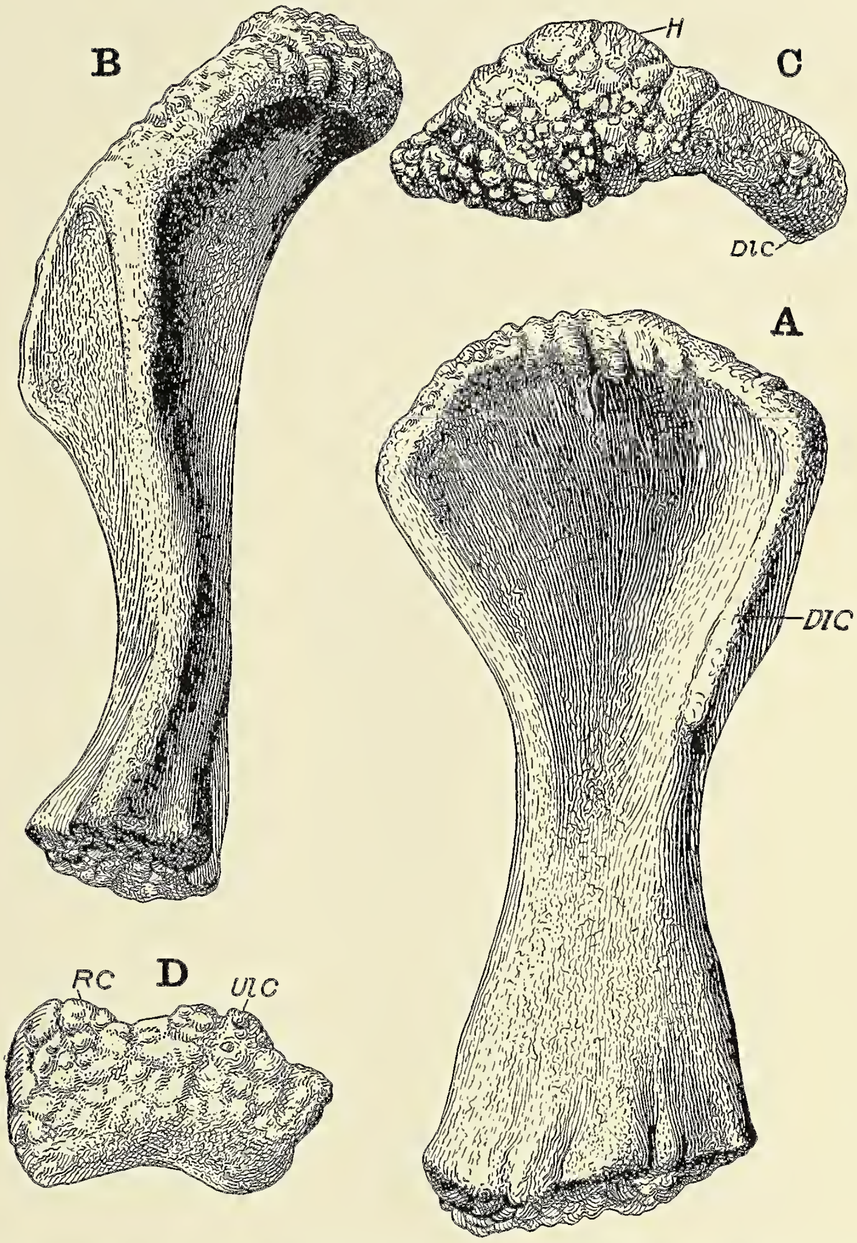

Fig. 11. Left humerus of *Apatosaurus louisæ* Holland. Type. No. 3018 C. M. *A.*, anterior view; *B.*, external view; *C.*, proximal view; *D.*, distal view; *Dl. C.*, deltoid crest; *H.*, head; *R. C.*, radial condyle; *Ul. C.*, Ulnar condyle. One-tenth natural size.

COMPARATIVE MEASUREMENTS OF HUMERI

	No. 3018 C. M.	No. 563 C. M.
	mm.	mm.
Greatest length	1150	1100
Greatest transverse diameter at proximal end	575	600
Greatest transverse diameter at distal end	415	410
Least transverse diameter of shaft	238	210
Ratio of length of humerus to length of femur	.69	.64

The radius and ulna.—The radius and ulna of the left fore limb were found articulated and these furnish corroborative evidence of the correctness of Hatcher's[29] determinations as to the proper articulation of these bones. That is, the proximal end of the radius is entirely enclosed by the ulna, posteriorly, see C, fig. 13, and thus the two elements did not cross, as first thought by some paleontologists, but remain more or less parallel in the articulated limb. The radius and ulna are subequal in length, the distal third of the ulna more slender than the corresponding part of the radius.

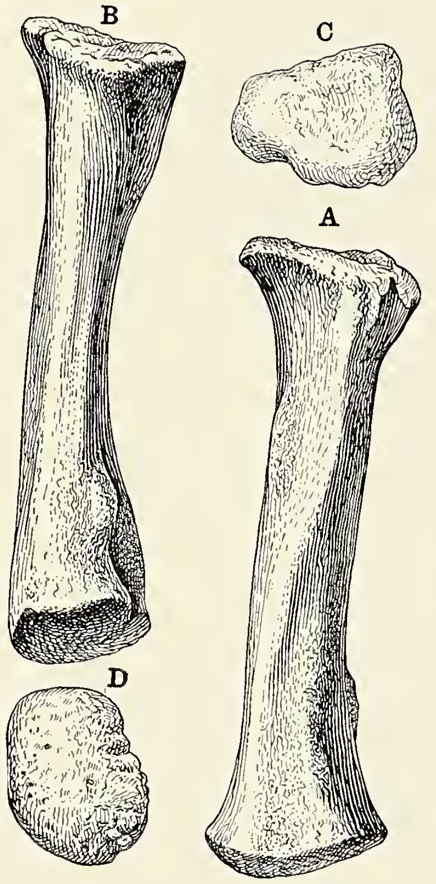

FIG. 12. Left radius of *Apatosaurus louisæ* Holland. Type. No. 3018 C. M. *A.*, anterior view; *B.*, external view; *C.*, proximal view; *D.*, distal view. One-tenth natural size.

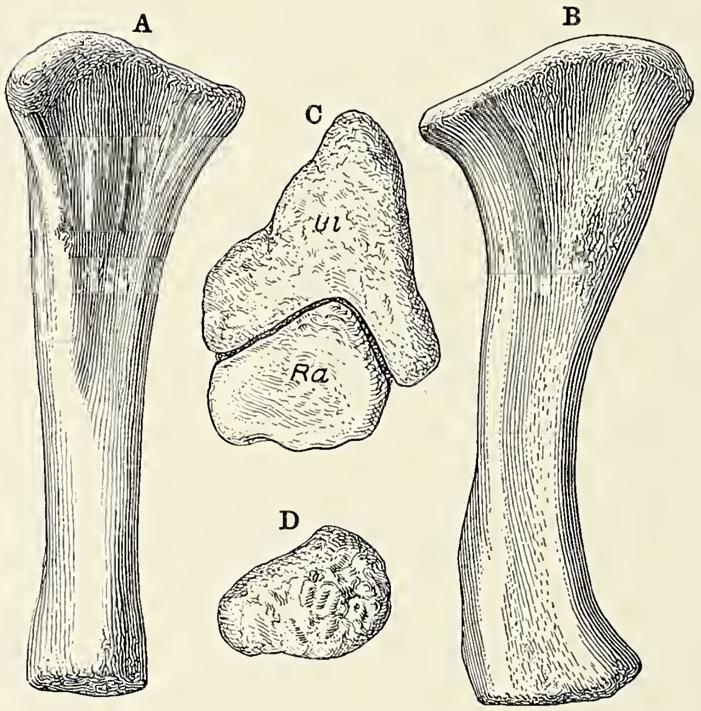

FIG. 13. Left ulna of *Apatosaurus louisæ* Holland. Type. No. 3018 C. M. *A.*, anterior view; *B.*, external view; *C.*, proximal ends of radius and ulna as found articulated; *D.*, distal end of ulna; *Ra.*, radius; *Ul.*, ulna. One-tenth natural size.

The radius has a slightly constricted shaft with subequally expanded ends. The proximal, see C, fig. 12, is slightly concave with a rugose surface. Distally there is a prominent rugosity on the posterior side near the external border. Opposite on the internal side of the ulna a similar rugosity near the distal end is

[29]Hatcher, J. B., Ann. Carnegie Museum, I, 1902, p. 363.

developed, and this doubtless indicates the points of attachment of important ligaments which bound these bones together. On the posterior surface near the distal end, the radius is hollowed out by a longitudinal groove which may have transmitted an artery. The distal end of the radius is subovate in outline with a convex rugose surface.

Viewed from above, see C, fig. 13, the ulna is triangular in outline with a deep concavity in front for the reception of the angularly rounded head of the radius. There is no olecranon process. The ulna gradually reduces in size toward the distal end which is subovate in outline and relatively smaller than the distal end of the radius. On the inner or radial side of the ulna, near the distal end, is a fossa for the reception of the rounded, posterior, external angle of the radius.

COMPARATIVE MEASUREMENTS OF RADIUS AND ULNA

	No. 3018 C. M.	No. 563 C. M.
	mm.	mm.
Greatest length of radius	800	755
Transverse diameter of radius at distal end	232	230
Fore and aft diameter of radius at distal end	118	105
Transverse diameter of radius at proximal end	240	240
Fore and aft diameter of radius at proximal end	180	95
Transverse diameter of radius at middle of shaft	125	127
Greatest length of ulna	850	740
Transverse diameter of ulna at distal end	170	155
Transverse diameter of ulna at proximal end	225	330

Carpus.

The carpus in *A. louisæ*, as in *Diplodocus*, consists of a single flattened bone of somewhat irregular shape. It has a rough resemblance to the scapho-lunar described by Hatcher[30] of specimen No. 563 C. M., but is thicker and more block-like. Viewed from above it is subrectangular in outline, thinning out toward the front and internal or radial side, and thickening toward the back. External to the antero-posterior line of greatest thickness, the bone abruptly thins to a small projecting lip that has a slightly concave upper surface that in articulation probably underlay the inner side of the distal end of the ulna. Internal to the antero-posterior line of greatest thickness the surface slopes off quite regularly to the inner margin. The posterior half of this surface is smooth and slightly concave, the

[30]Hatcher, J. B., Annals Carnegie Museum, Vol. I, 1902, pp. 366-367.

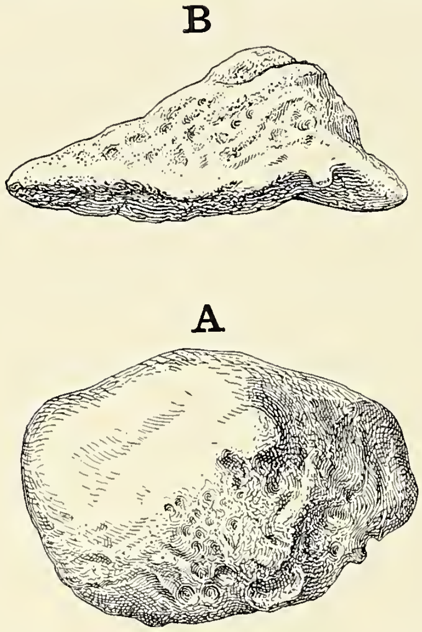

Fig 14. Left scapho-lunar of *Apatosaurus louisæ*. Type. No. 3018 C. M. *A.*, superior view; *B.*, posterior view. One fourth natural size.

anterior half rugosely roughened. If the surfaces have been correctly interpreted, this larger inner surface would lie below the distal end of the radius.

The ventral side of the scapho-lunar[31] is nearly flat with an irregularly roughened surface. If properly articulated on the skeleton, as it seems to be, it is in articulation with metacarpals II, III, and IV. The principal features of this bone are clearly shown in fig. 14.

COMPARATIVE MEASUREMENTS OF SCAPHO-LUNAR

	No. 3018 C. M.	No. 563 C. M.
	mm.	mm.
Greatest transverse diameter	207	203
Greatest fore and aft diameter	140	155
Greatest thickness	80	55

[31]In *Camarasaurus* (*Morosaurus*), Osborn (Bull. Amer. Mus. Nat. Hist., Vol. XX, 1904, p. 182) found two carpal elements, the larger of which appears to fit by distinct facets on top of Mtc. I and Mtc. II. From this discovery he concludes these bones represent the coalesced carpalia of the distal row. If this is the correct interpretation, instead of being the scapho-lunar (radiale+intermedium) this single carpal element in *Apatosaurus* would represent coalesced carpalia 1, 2, and 3 of the distal row of the carpus. For the present, however, I shall continue to use the original designation.

Manus.

The left fore foot is the only one preserved and was found in position in the matrix at the extremity of the completely articulated fore limb as shown in fig. 15. Metacarpals, I, II, III, IV, and V were in regular order interlocked at their proximal ends. The position of metacarpals I and II in relation to metacarpals III, IV, and V is such as to indicate that the proximal ends of these bones were arranged in the arc of a circle and thus were better adapted to sustain the great weight imposed upon them. In addition to the metacarpals, proximal phalanges of digits I and II were found nearly in position, as was the single large ungual of the first digit and a small sesamoid-like element in close proximity to the distal extremity of the proximal phalanx of the second toe. The other phalangials are all missing from this foot.

The presence of a single ungual gives further support to the idea that in the manus of the Sauropodous dinosauria there is but a single clawed ungual. On the mounted skeleton the fore feet have been restored with additional phalangials and

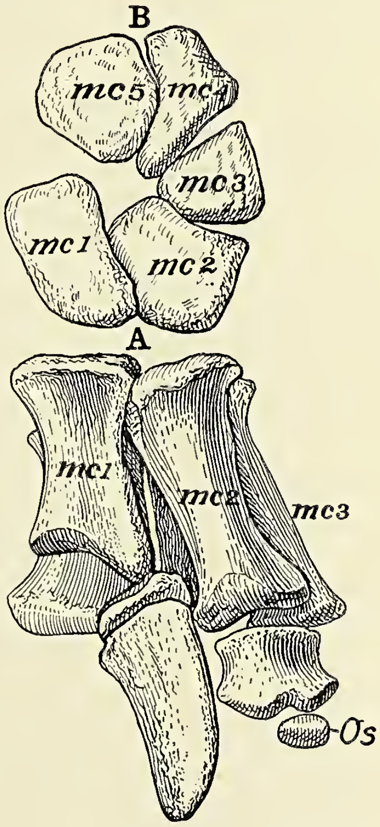

Fig. 15. Left fore foot of *Apatosaurus louisæ* Holland. Type. No. 3018 C. M. *A.*, Showing the bones of the manus as found in the matrix. *B.*, Proximal ends of the metacarpals as found. *Mc* 1, *mc* 2, *mc* 3, *mc* 4, and *mc* 5, metacarpals one to five. About one-ninth natural size.

unguals on digits II and III respectively. In view of the fact that a considerable number of articulated fore feet of the Sauropoda are now known and that none has been discovered with more than a single clawed ungual in association, the negative evidence thus accumulated seems to indicate there was only one, and that the foot as restored is in error in that respect. Until a manus is found having additional unguals in position, or at least in close association, it is my belief that there is no justification at this time for the addition of extra claws. Some uncertainty also exists as to the precise number of phalanges composing the complete *Apatosaurus* fore foot. The most perfect manus yet known is the one described by Hatcher (Annals Carnegie Museum, vol. I, 1901, pp. 366-374) see fig. 35, which has a complete proximal row of phalanges, a clawed ungual on digit I, and a sesamoid element whose exact position may still be considered uncertain although found on the palmar side of the foot lying between the distal end of mc. III and its proximal phalanx. The presence of a similar element at the end of the proximal phalanx of digit II in the present specimen leads to the suggestion that perhaps these ossicle-like elements are not sesamoids but represent the remnants of degenerating toe bones, nothing more than functionless ossicles, similar to those found in practically the same position on digits IV and V of the pes in both *Apatosaurus* and *Diplodocus*.

The phalangial formula of *Apatosaurus* as positively known at the present time is 2, 1, 1, 1, 1, or if the ossifications are phalangial remnants as has been suggested, the formula would be 2, 2, 2, 1, 1, a more probable arrangement. It will be only by the discovery of more completely preserved feet that the point raised can ever be established.

The whole structure and arrangement of the metacarpus and phalanges is so modified as to indicate that the principal weight of the body was supported by the manus on the inner side of the foot.

Metacarpals.—The metacarpal bones of *A. louisæ* so closely resemble those of *A. excelsus* (No. 563 C. M.) described in detail by Hatcher (see pages 257 to 260) that at this time it appears only necessary to call attention to those features in which they differ.

The metacarpals of *A. louisæ* are normal uncrushed bones, whereas the pes of *A. excelsus* No. 563 C. M. has suffered from vertical compression, and the articular ends have been considerably altered by this crushing, a condition for which Hatcher made some allowance in his description.

Metacarpal I of No. 3018 C. M., except for its slightly larger size, corresponds closely in all of its main characteristics with the first metacarpal of No. 563 C. M.

The articular ends of the last mentioned bone have been much compressed

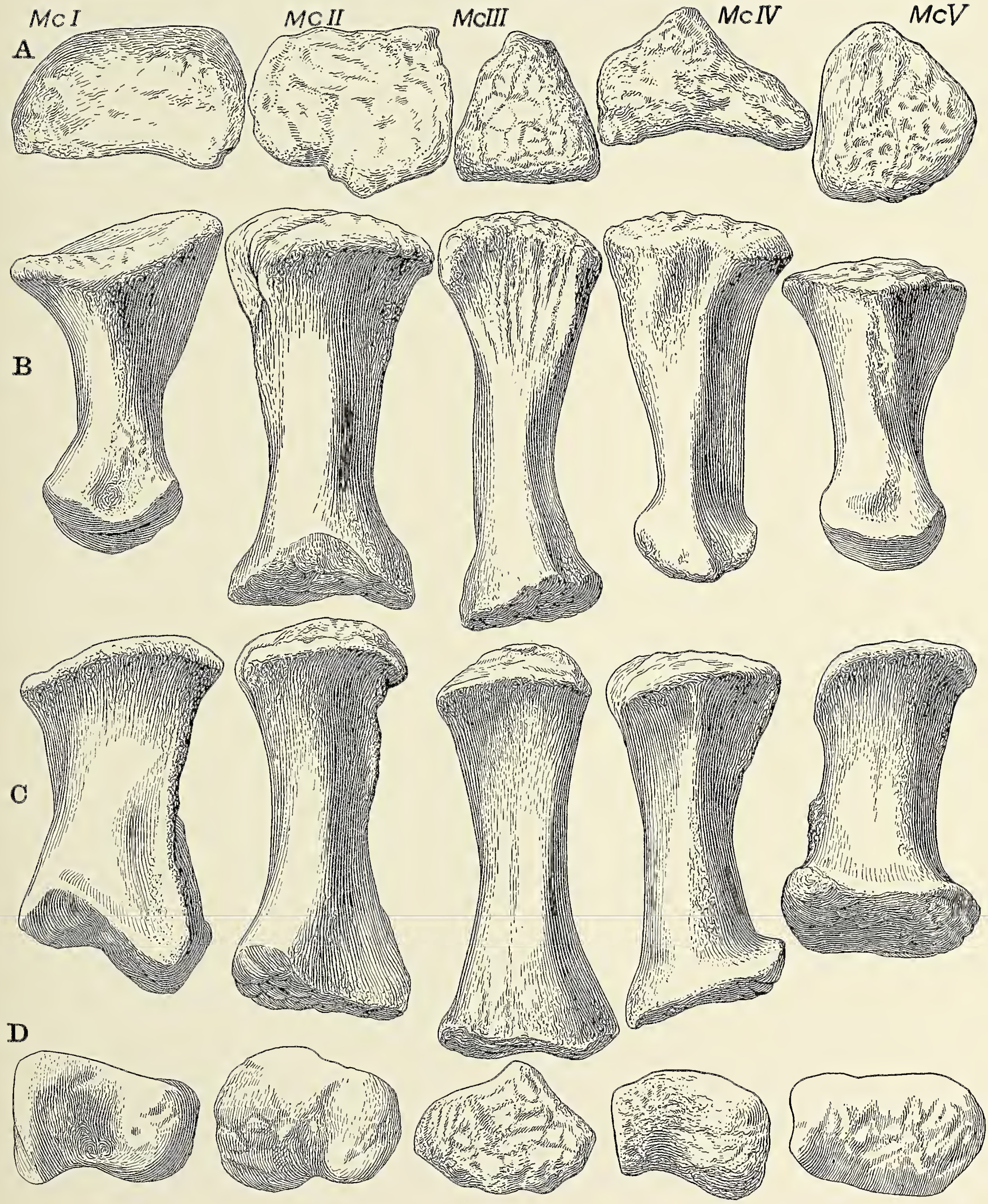

FIG. 16. Left metacarpals of *Apatosaurus louisæ*. Type. No. 3018 C. M. *A.*, proximal views; *B.*, lateral views; *C.*, anterior views; *D.*, distal views. Mc. I, Mc. II, Mc. III, Mc. IV, Mc. V, metacarpals one to five respectively. All one-fourth natural size.

which will in great measure account for the considerable differences shown in the diameters of the articular ends of these bones in the table of comparative measurements.

Metacarpal II has the proximal end deeper than wide, whereas, due to crushing, metacarpal II of No. 563 C. M. is wider than deep. The surface of this end is regularly convex in all directions. A plane passed through the greatest diameter of the proximal end would bisect the line of greatest diameter of the distal end at an angle of nearly 45 degrees. In this same bone of No. 563 C. M. these two diameters are in the same transverse plane. The distal end is broader than deep, the surface being regularly convex vertically, and shallowly concave transversely. The outline of the uncrushed proximal end is well shown in A, fig. 16.

Metacarpal III, except for the more robust character of the articular ends, is in close accord with the third metacarpal of No. 563 C. M., described in detail on page 259.

The uncrushed proximal end of metacarpal IV is subtriangular in outline, see A, fig. 16, the lines bounding the internal and superior borders are subequal in length and meet at right angles. The hypotenuse of this triangle is formed by the regularly concave line of the outer border. The inner border is shallowly indented for articulation with Metacarpal III, not deeply emarginated as in Metacarpal IV of No. 563 C. M., a condition plainly exaggerated by vertical crushing. In all other respects the two bones are in agreement.

Metacarpal V is the shortest bone of the series, but very stout in this specimen. In outline the proximal end is subround, see A, fig. 16, the articular surface being convex in all directions. This end of No. 563 C. M. is crescentic in shape, and entirely unlike Metacarpal V of No. 3018 C. M., though doubtless the former has been somewhat altered by crushing. The inner side of Metacarpal V of No. 3018 C. M., at the proximal end, presents a flattened surface for articulation with Metacarpal IV. The superior or front surface of this element, see fig. 16, is broad and gently convex transversely. The distal end is expanded in all directions. Viewed from the end it is quadrangular in outline, with the longest diameter transverse, as contrasted with the subround end of the fifth metacarpal of No. 563 C. M.

Such differences as have been found in the metacarpal bones of these two specimens may for the most part be attributed to distortion brought about by the vertical crushing to which the manus of No. 563 C. M. has been subjected. With the exception of Metacarpal V all of the other elements are in close accord.

Phalanges.—The proximal phalanx of digit I of *A. louisæ* differs from the same bone of No. 563 C. M. in the lack of a palmar flange extending backward under the distal articular end of Metacarpal I. This feature of the No. 563 C. M. bone,

however, is quite certainly exaggerated by crushing. In all other respects the two bones are very similar.

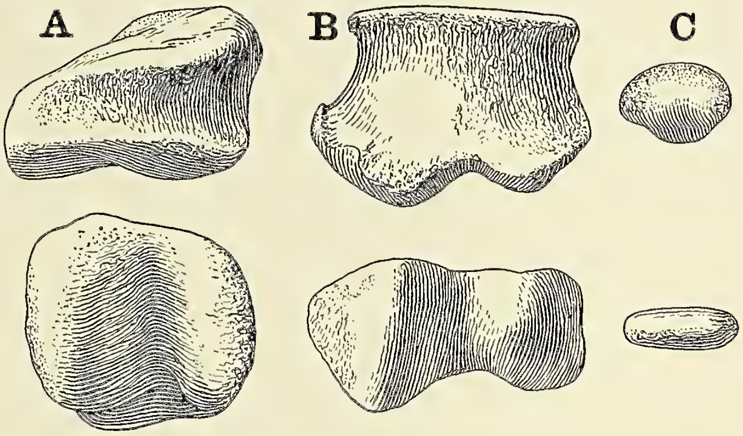

FIG. 17. Phalanges of left fore foot of *Apatosaurus louisæ*. Type. No. 3018 C. M. *A.*, proximal phalanx, digit I; *B.*, proximal phalanx, digit II: *C.*, Ossicle-like phalanx found at distal end digit II. All one-fourth natural size.

The proximal phalanx of digit II is in full accord with the corresponding element of specimen No. 563 C. M.

The ungual phalanx of digit I differs so entirely from the homologous bone of No. 563 C. M. as to require a detailed description, especially since the pointed ungual of that foot is abnormal, a condition partly recognized by Hatcher at the time of describing it.

This ungual is a deep, compressed, slightly curved bone, with a squarely truncated anterior extremity, see fig. 18. The internal surface is strongly convex from

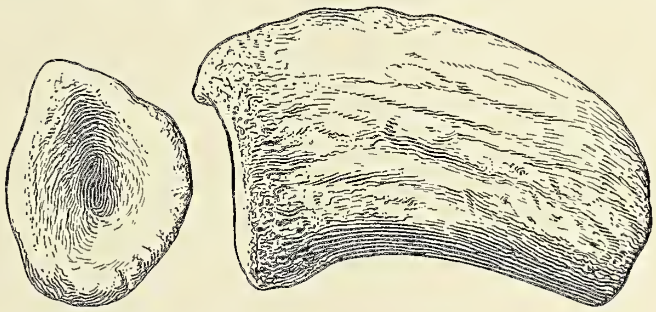

FIG. 18. Ungual phalanx of digit I of left manus of *Apatosaurus louisæ*. Type. No. 3018 C. M. Lateral and end views. One-fourth natural size.

above downward, the external nearly flat. The proximal end is deeply cupped as shown in fig. 18. The truncated anterior end presents a bluntly obtuse edge. The surfaces of the bone are roughened, with the customary longitudinal groove on the lower internal surface. The ungual as a whole is less curved on the ventral border than the unguals of the pes.

The principal dimensions of these bones of the foot are given below in the table of comparative measurements.

COMPARATIVE MEASUREMENTS OF METACARPALS

Meta-carpal	Greatest length		Greatest transverse diameter proximal end		Greatest transverse diameter distal end		Least diameter of shaft		Greatest diameter antero-posterior proximal end	
	No. 3018 C. M.	No. 563 C. M.	No. 3018 C. M.	No. 563 C. M.	No. 3018 C. M.	No. 563 C. M.	No. 3018 C. M.	No. 563 C. M.	No. 3018 C. M.	No. 563 C. M.
	mm.	mm.	mm.	mm.	mm.	mm.	mm.	mm.	mm.	mm.
I	265	257	100	80	147	103	69	70	175	155
II	285	285	130	122	140	149	77	80	152	85
III	293	285	113	110	130	119	59	70	115	74
IV	245	240	125	76	124	110	62	60	130	125
V	235	232	130	68	144	110	68	57	137	142

MEASUREMENTS OF PHALANGIALS

	Length		Greatest breadth		Greatest depth proximal end		Greatest depth distal end	
	No. 3018 C. M.	No. 563 C. M.	No. 3018 C. M.	No. 563 C. M.	No. 3018 C. M.	No. 563 C. M.	No. 3018 C. M.	No. 563 C. M.
	mm.	mm.	mm.	mm.	mm.	mm.	mm.	mm.
Proximal phalanx, digit I..	76	75	120	105	95	85	90	83
Proximal phalanx, " II.	100	90	138	138	99	100	76	75
Proximal phalanx, " III	...	67	...	130	...	65	...	23
Proximal phalanx, " IV	...	68	...	109	...	66	...	42
Proximal phalanx, " V.	...	75	...	125	...	70	...	52
Ungual, digit one........	215	205	95	64	130	125	...	...

The Pelvis.

All of the pelvic bones are present in specimen No. 3018 C. M. and were found in articulated position with the sacrum. The coössification of the pubes with the ischia, and the further coössification of the latter with each other at their distal ends, establishes beyond question the true relationships of the bones forming the pelvic girdle. The pubes and ischia in the mounted skeleton are more divergent than first indicated by Marsh, but they are in exact accord with the skeleton of *Apatosaurus excelsus* in the Field Museum which has the pubes and ischia similarly coössified.

Ilium.—The ilia are both incomplete. The left lacks the anterior process in front of the pubic peduncle and most of the superior crest, the right has the anterior end fairly complete with the exception that much of the upper half is missing.

The illustration shown in fig. 19 has been drawn from both ilia with the superior border restored from No. 563 C. M., which has the left ilium completely preserved as shown in fig. 36. Below on the inner side it articulates with the five coalesced

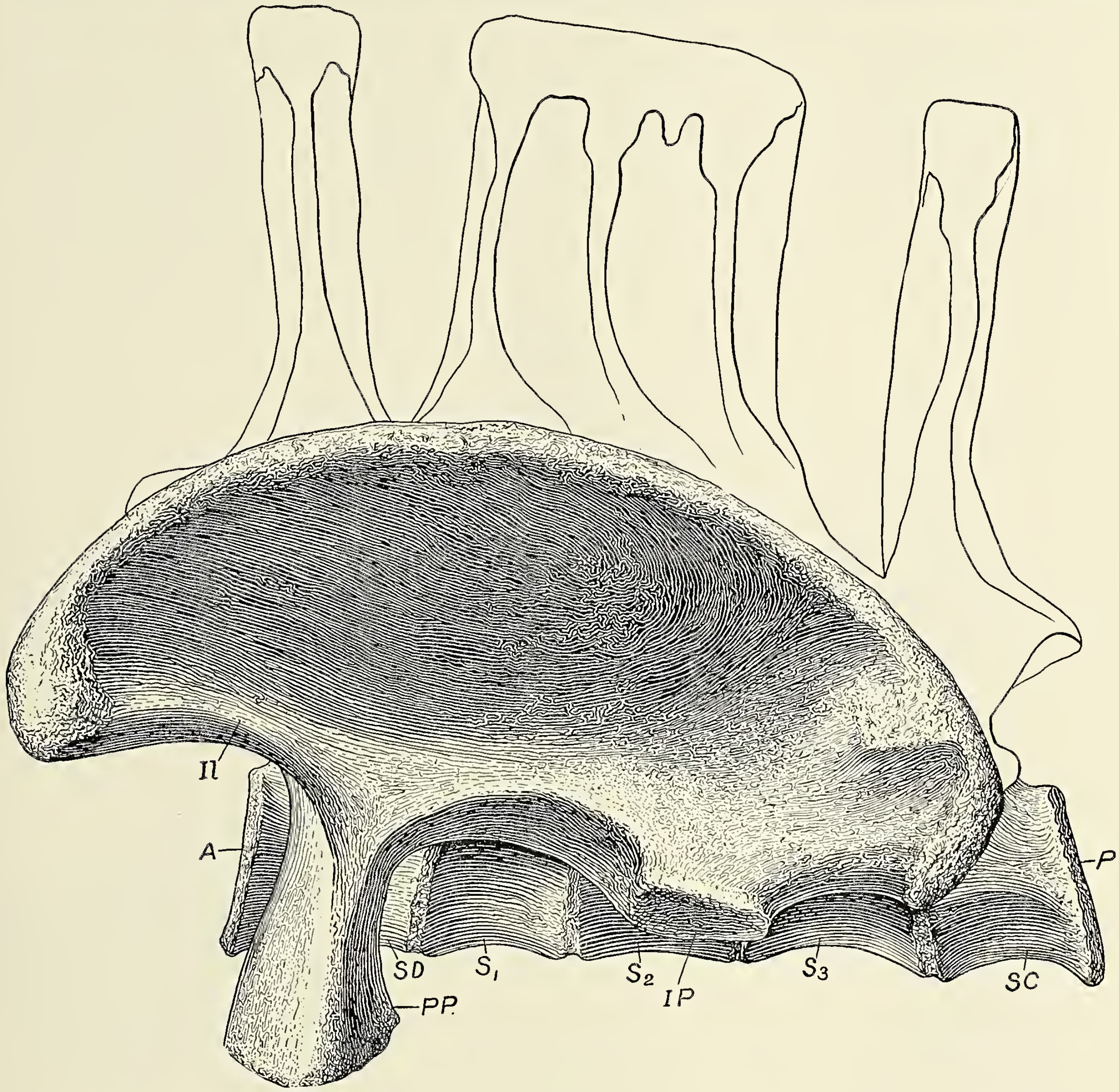

FIG. 19. Left ilium and sacrum of *Apatosaurus louisæ*. Type. No. 3018 C. M. Viewed from the left side. The ilium partly restored from the right. *A.*, anterior end; *Il.*, ilium; *I.p.*, ischiac peduncle; *P.*, posterior end; *P.p.*, pubic peduncle; *S.c.*, sacrocaudal; *S.d.*, sacrodorsal; S.1, S.2, S.3, primary caudals one to three. One-tenth natural size.

sacral ribs and the corresponding diapophyses which are now completely hidden in this specimen. The ilium is produced far in front of the pubic peduncle into a

broad but gradually narrowing anterior blade. This anterior blade is obtusely pointed as in *Diplodocus*, not broad as in *Haplocanthosaurus*. The lower border of the blade forms nearly a right angle with the anterior border of the pubic peduncle, as in the type of *B. excelsus* in contrast to the acute angle found in other specimens of the latter species.

Pubis.—The pubes are proportionally short and stout with expanded ends, especially the proximal. They are much thickened at the acetabular border. The pubis articulates proximally with the great peduncle of the ilium and laterally with the ischium by a long, nearly vertical suture that extends downward from the acetabulum. This suture is fully coalesced on both sides. The distal ends are moderately enlarged; they are united, probably by cartilage, on the median line

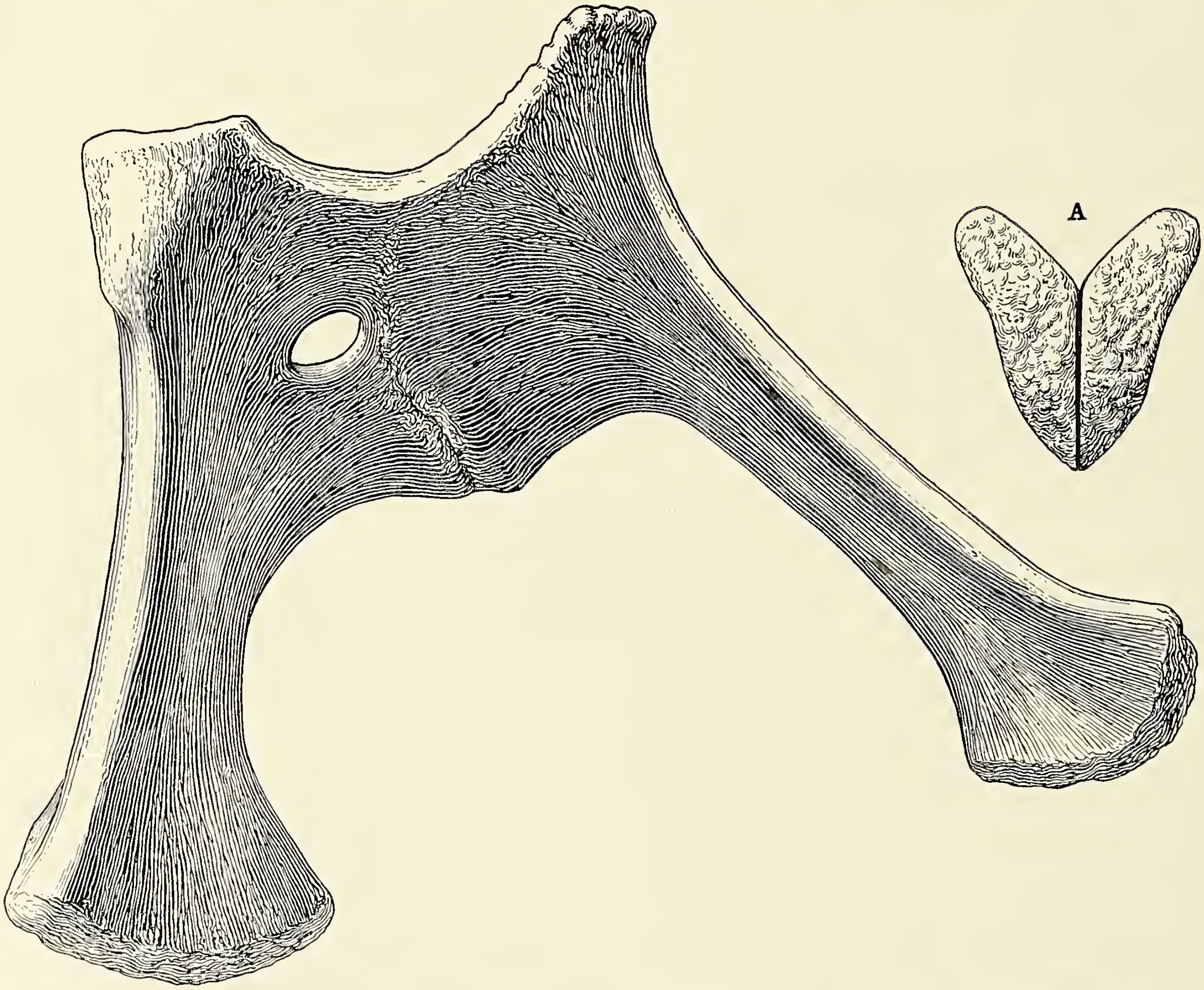

FIG. 20. Left coössified ischium and pubis of *Apatosaurus louisæ*. Type. No. 3018 C. M. Lateral view; *A.*, coössified distal ends. One-tenth natural size.

and again at a point at their midlength. An elongated slot separates the inner borders between these two points of contact. A pubic foramen opens downward immediately below the anterior border of the acetabulum. The end for articulation with the greater peduncle of the ilium is concave. The broadly expanded proximal ends of the pubes are concave internally and convex externally.

Ischium.—The ischia of *Apatosaurus* are longer and more slender than the pubes. The broadly expanded proximal end presents two articulating surfaces, an upper that unites by cartilaginous union with the lesser peduncle of the ilium, a lower with the pubis by the anterior margin of the blade. Between the two articular surfaces the border is concave antero-posteriorly and contributes to the boundary of the acetabulum. Posterior to the proximal end the shaft curves strongly mesial to meet its fellow of the opposite side on the median line, at about midlength.

In this specimen the two ischia are firmly coössified throughout the length of this contact. The distal end is somewhat expanded but more especially on the posterior side. Viewed from the end the cojoined ischia present a heavy U-shaped termination with rugosely roughened surfaces. See A., fig. 20.

COMPARATIVE MEASUREMENTS OF PELVIC BONES

	A. louisæ No. 3018 C. M.	*A. excelsus* No. 563 C. M.
	mm.	mm.
ILIUM		
Length over all	1460	1280
Acetabulum to superior border about	570	450
Diamater from pubic to ischiac peduncle	460	445
PUBES		
Length over all	1190	950
Greatest breadth of proximal end	...	425
Greatest breadth of distal end	270	300
Least breadth of shaft	105	150
ISCHIA		
Length over all	1275	1075
Greatest breadth of proximal end	500	600
Greatest breadth of distal end	335	300
Least diameter of shaft	105	100
Transverse diameter of coalesced distal ends	345	...

HIND LIMB.

The hind limbs are represented by the right femur, tibia, fibula, and astragalus, and the greater portion of the left pes.

Femur.—The right femur is almost perfectly preserved and being free from distortion gives a perfect idea of the shape and proportions of this important bone.

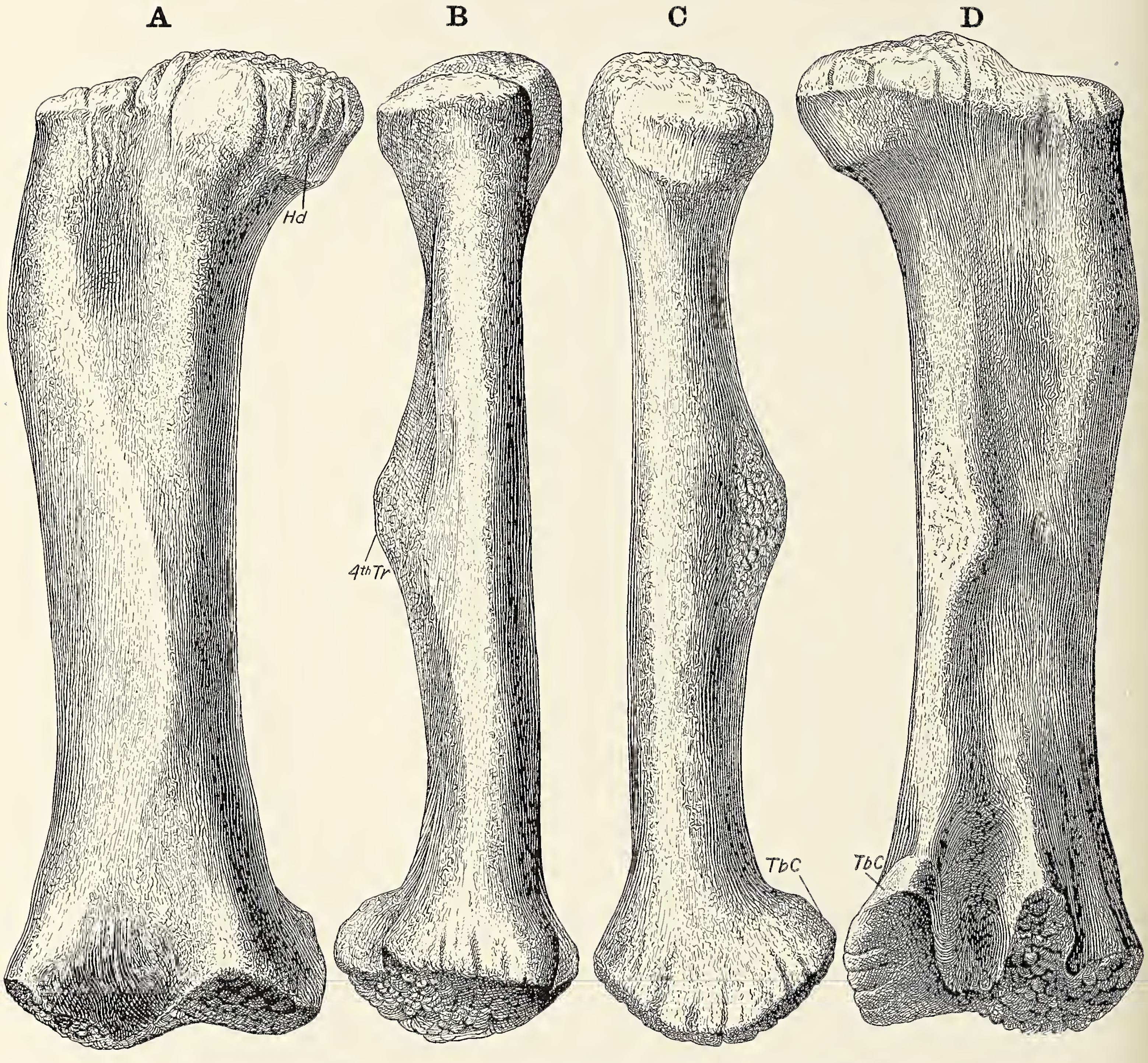

Fig. 21. Right femur of *Apatosaurus louisæ.* Type. No. 3018 C. M. *A.*, front view; *B.*, external view; *C.*, internal view; *D.*, back view; *Hd.*, head; *Tb.c.*, tibial condyle; 4th *tr.*, fourth trochanter. One-tenth natural size.

The femur is a stout bone, in fact stouter than in any other known member of the Sauropoda except the unusually stout-limbed *A. amplus* Marsh. The head is rugosely roughened and rises above the level of the great trochanter. The shaft in cross-section is flattened antero-posteriorly and widened transversely so that in cross-section it would be ovate in outline. As in other Sauropod femora, the head is not distinctly separated from the shaft but the rugose surface of the latter is continued uninterrupted and covers the superior surface of the great trochanter. The fourth trochanter exists as a strongly developed ridge, developed on the postero-internal angle of the shaft, and located somewhat above midlength. In *Diplodocus*, Hatcher erroneously designates this as the third trochanter. In *Camarasaurus*, Osborn and Mook (Mem. Amer. Mus. Nat. Hist., III, pt. 3, 1921, p. 365) point out that the apex of the fourth trochanter is exactly at midlength of

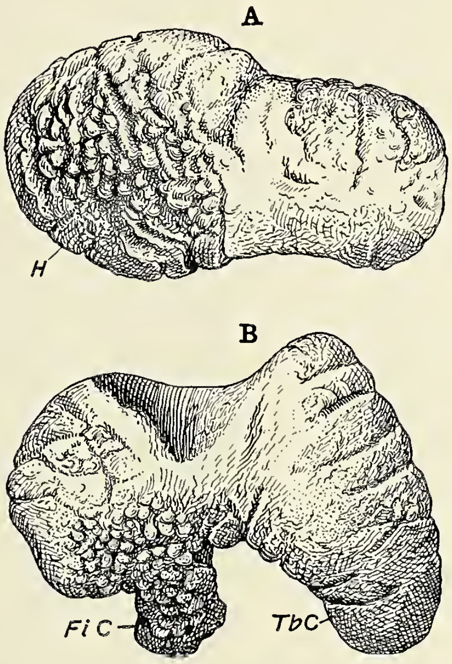

Fig. 22. Articular ends of femur of *Apatosaurus louisæ*. Type. No. 3018 C. M. *A.*, proximal end; *B.*, distal end; *Fi.C.*, fibular condyle; *H.*, head; *Tb.C.*, tibial condyle. One-tenth natural size.

the bone. This may, however, be only an individual characteristic. The external and internal condyles are separated by a deep intercondylac groove the inner one being much the larger. The outer one is cleft by a deep, fibular groove. Compared with the femur of the Field Museum *Apatosaurus* specimen the closest resemblances are found throughout. The principal features of this bone are clearly shown in figs. 21 and 22.

COMPARATIVE MEASUREMENTS OF FEMORA

	No. 3018 C. M.	No. 563 C. M.	No. 7163 F. M.
	mm.	mm.	mm.
Greatest length	1785	1710	1830
Greatest breadth at proximal end	575	543	570
Greatest breadth at distal end	565	515	590
Least diameter of shaft	320	260	310

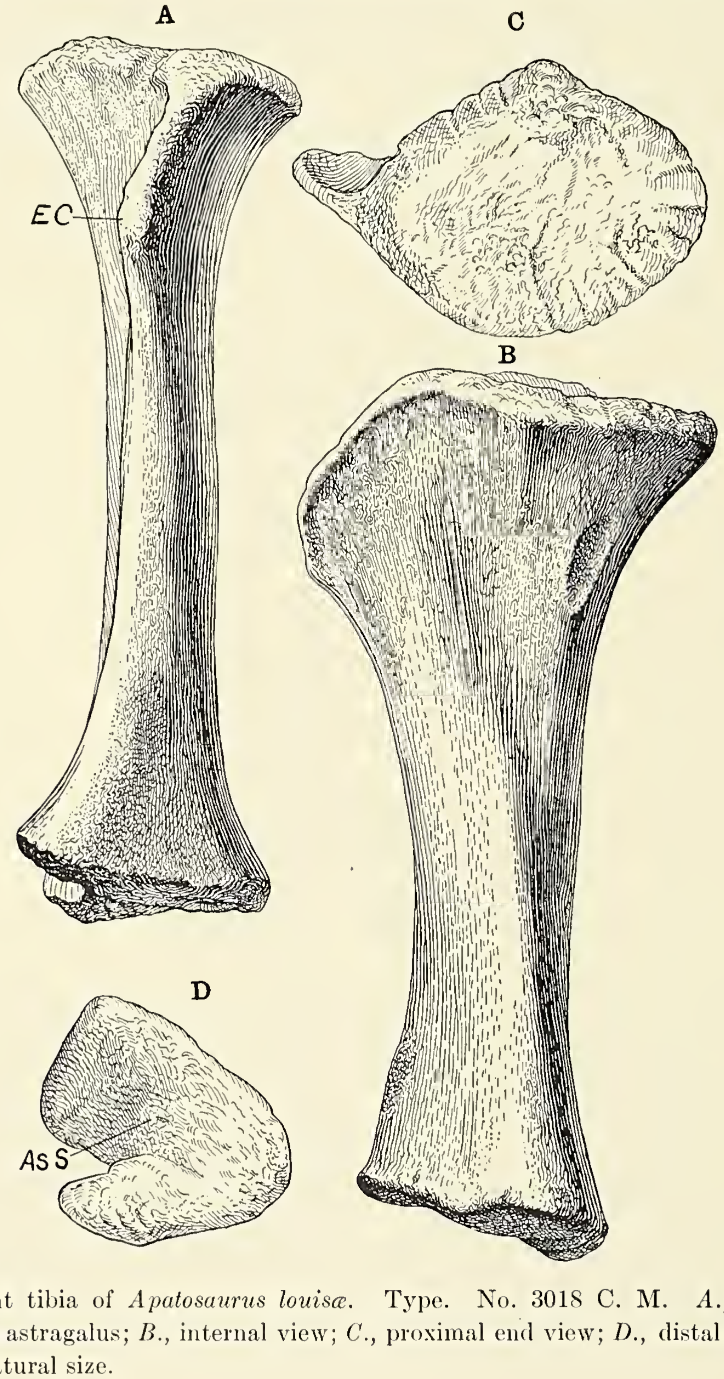

FIG. 23. Right tibia of *Apatosaurus louisæ*. Type. No. 3018 C. M. *A.*, front view; *As.S.*, articular surface for astragalus; *B.*, internal view; *C.*, proximal end view; *D.*, distal view; *E.c.*, cnemial crest. One-tenth natural size.

Tibia and fibula.—The right tibia and fibula preserved with specimen No. 3018 C. M. are hardly to be distinguished from the corresponding bones of *Camarasaurus*, although both can be readily differentiated from the lower limb bones of the more slender *Diplodocus*.

The tibia of *Apatosaurus* is considerably shorter than the femur. The proximal end is more expanded than the distal principally in a transverse direction. The thick enemial crest is located on the anterior internal angle and partly locks the fibula in position. Viewed from above, see C, fig. 23, the proximal end is angularly rounded the entire surface being rugosely roughened. The shaft of this bone is

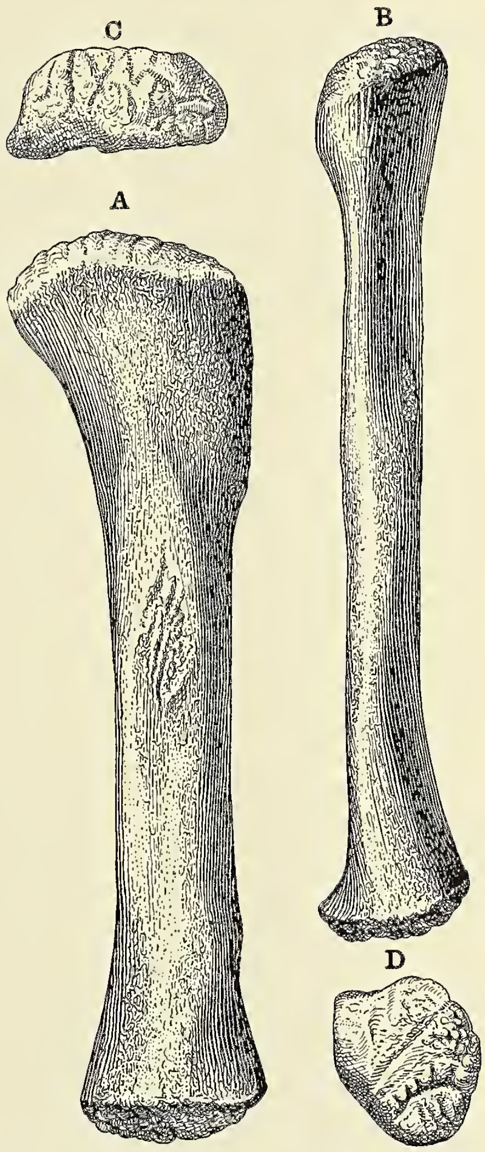

FIG. 24. Right fibula of *Apatosaurus louisæ*. Type. No. 3018 C. M. *A.*, lateral view; *B.*, posterior view; *C.*, proximal end view; *D.*, distal end view. One-tenth natural size.

comparatively thick, but constricted in regard to the ends. On its internal and posterior distal extremity it sends downward an internal malleolus that is separated from the main shaft of the bone by a vertical groove for the transmission of the tendons of the muscles of the foot. This process is in articulation with the posterior and internal surface of the astragalus. The features of this bone are clearly set forth in fig. 23.

The fibula is much more slender than the tibia and exceeds it in length. When in an articulated position it extends well below the distal end of the tibia and abuts against the outer side of the astragalus. As in *Diplodocus* it has displaced the calcaneum and nearly reaches the proximal ends of metatarsals IV and V. The proximal end is slightly expanded antero-posteriorly but the width of the shaft remains subequal throughout its length, see fig. 24, with very slight enlargement of the distal end. The whole bone is flattened transversely but more especially on the inner side of the proximal end where it articulates with the tibia. A thinned anterior edge fits into the broad groove formed by the recurved enemial crest of the tibia. On the external surface of the fibula, slightly above its midlength, is a vertically ovate roughened area indicating a point of insertion for a large muscle. The distal end of this bone is subround in outline. The internal side of this end in articulation projects inward beneath the tibia to meet the astragalus.

COMPARATIVE MEASUREMENTS OF TIBIA AND FIBULA

	No. 3018 C. M.	No. 563 C. M.
	mm.	mm.
Greatest length of tibia	1115	1010
Greatest breadth at proximal end	545	445
Greatest breadth at distal end	345	348
Greatest length of fibula	1175	1095
Greatest breadth at proximal end	310	...
Greatest breadth at distal end	240	245

The Pes.

The hind foot, as represented in specimen No. 3018 C. M., consists of the right astragalus; and the following elements of the left pes; metacarpals I, II, III, and IV; the complete row of proximal phalangials, two phalangials of the second row pertaining to digits II and III; and three unguals. The missing bones have been restored from a complete foot, No. 89 in the Carnegie Museum collections, and thus the digital formula for *Apatosaurus* can now be stated as 3, 4, 5, 3, 2. A rough

measurement of the articulated foot shows it to have a transverse width of about 31 inches, and a length of about 27 inches.

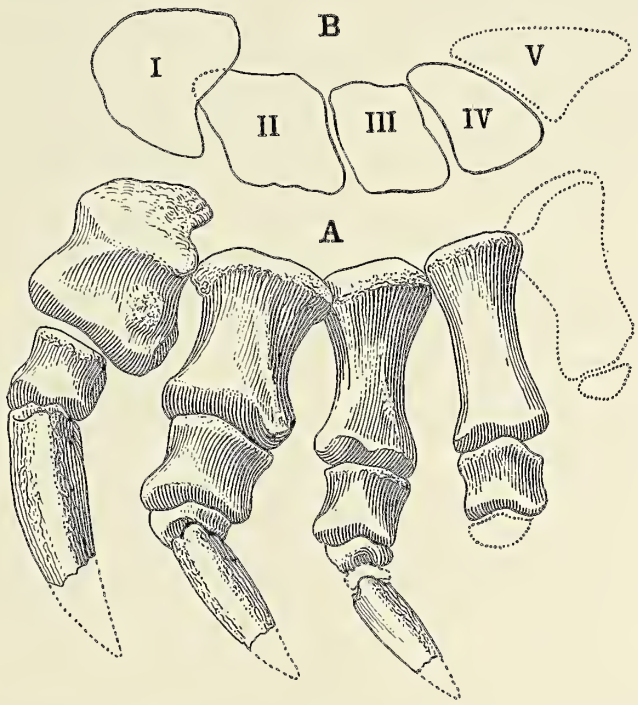

FIG. 25. Articulated hind foot of *Apatosaurus louisæ*. Type. No. 3018 C. M. *A.*, superior view; *B.*, proximal view. Metatarsals one to four. About one-ninth natural size.

Tarsus.—The osseous portion of the tarsus in *Apatosaurus* as in *Diplodocus* and *Camarasaurus* consists of the astragalus. In the present specimen this bone was not fused with the distal end of the tibia as often happens in aged individuals, but was found free. It is a heavy, sub-triangular shaped bone, that in the articulated limb is entirely covered superiorly by the distal end of the tibia. The anterior surface of the astragalus presents a broad, regular convex face for the articulation with the proximal ends of metatarsals I, II, and III, and the inner proximal end of metatarsal IV. The external end, the deepest portion, is deeply excavated. A projecting inferior margin having a superior articular surface was opposed by the inner distal end of the fibula. Posteriorly, toward the outer end the astragalus develops a heavy, wide vertical ridge which separates the external cavity from a smaller internal excavation as clearly shown in fig. 26. Inferiorly the astragalus has a broad, rugose, regularly convex plantar surface.

MEASUREMENTS OF ASTRAGALUS.

Greatest transverse diameter of astragalus	320 mm.
Greatest depth about	186 mm.

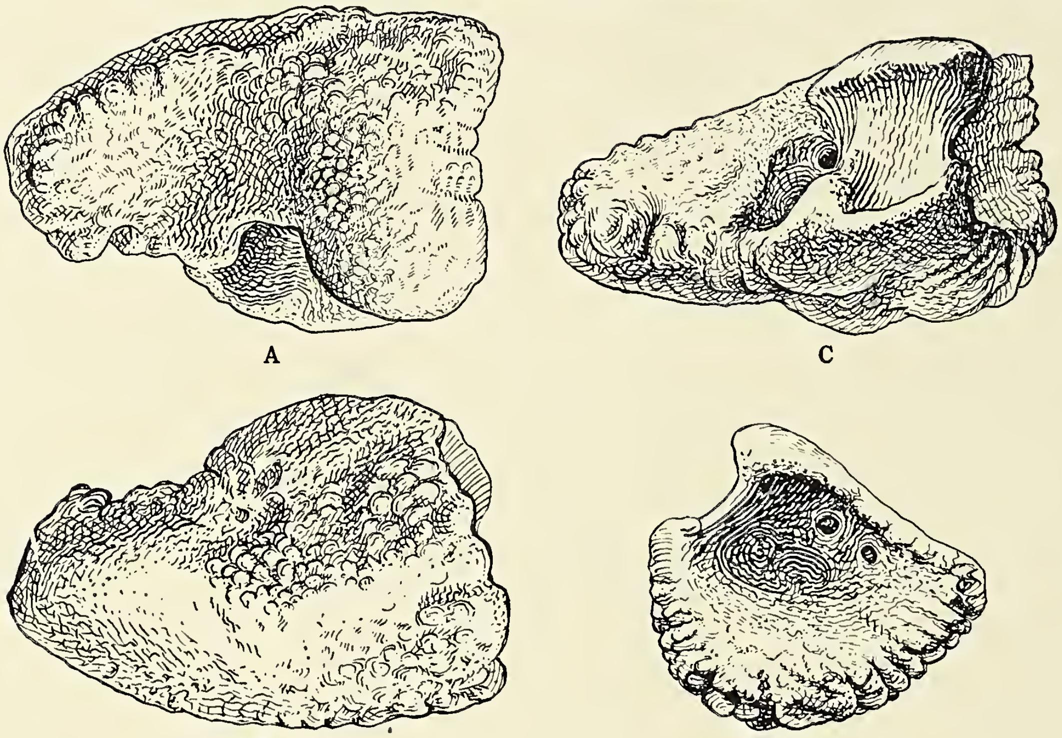

Fig. 26. Right astragalus of *Apatosaurus louisæ*. Type. No. 3018 C. M. *A.*, superior view; *B.*, inferior view; *C.*, posterior view; *D.*, external view. One-fifth natural size.

Metatarsals.—The metatarsus is composed of five well developed functional metatarsal bones. Metatarsal I is the shortest and stoutest bone of the series. It is constricted medially, expanded vertically at the proximal and transversely at the distal ends. The articular end surfaces are strongly oblique to one another, converging toward the inner side of the foot. The proximal surface is nearly flat, the distal strongly convex antero-posteriorly. The medial third of this end projects prominently downward from the remainder of this surface as shown in fig. 27. The external lateral margin of the proximal end is deeply concave antero-posteriorly for articulation with the convex internal margin of metatarsal II.

Metatarsal II is slightly longer and less stout than metatarsal I, although decidedly stronger than metatarsal III. It is somewhat constricted both in vertical and lateral diameters. The proximal end is trapezoidal in outline, the distal end subrectangular. A prominent rounded ridge is developed on the front surface and extends diagonally downward to the distal exterior angle. The distal articular end presents a regularly convex articular surface antero-posteriorly; but is concave transversely. This surface is for the accommodation of the low median keel of the proximal phalanx. The detailed features of this bone are clearly depicted in A, B, C, and D, fig. 27.

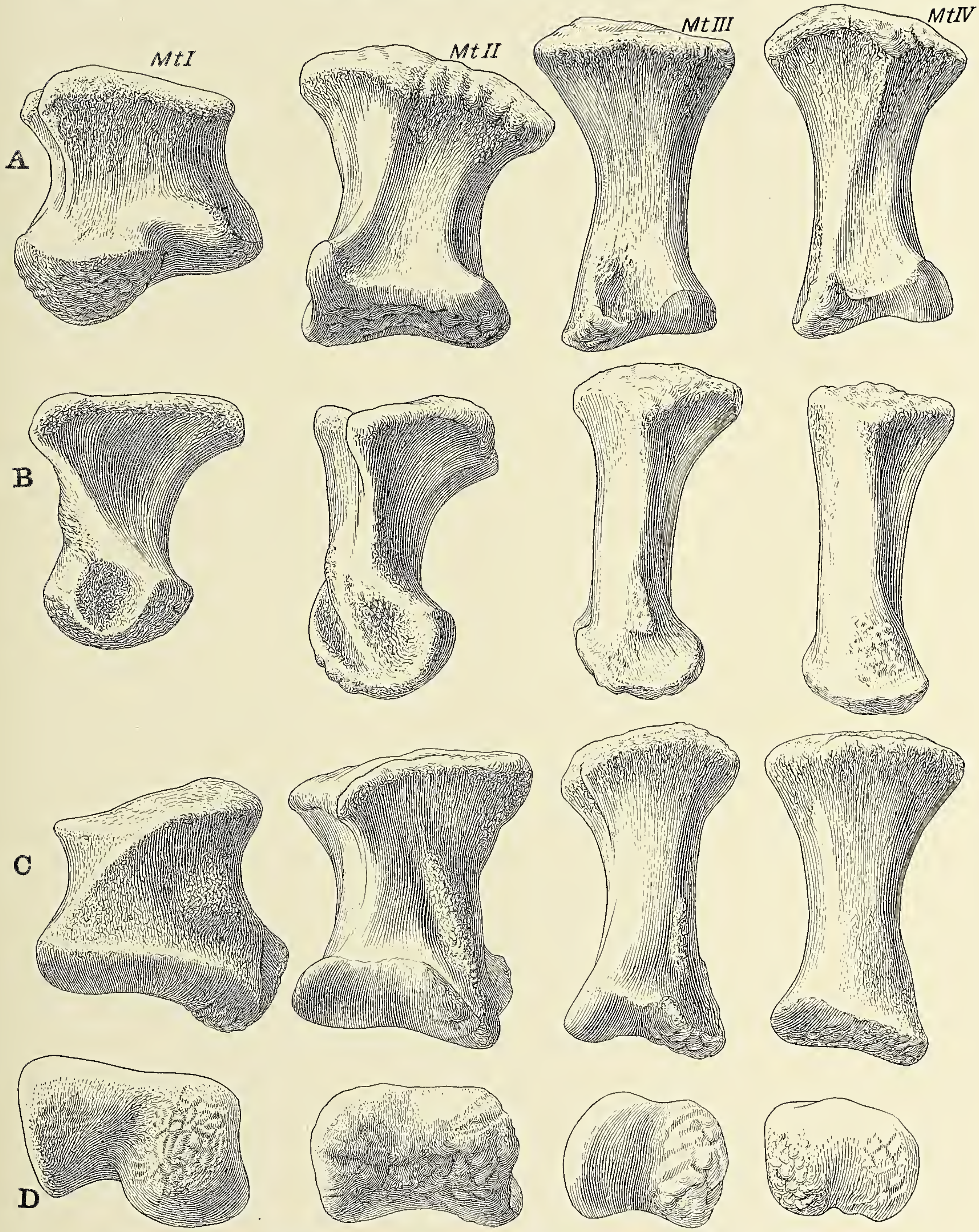

FIG. 27. Left metatarsals of *Apatosaurus louisae*. Type. No. 3018 C. M. *A.*, posterior views; *B.*, external views; *C.*, anterior views; *D.*, distal views. Mt. I, mt. II, mt. III, mt. IV, metatarsals one to four respectively. All one-fourth natural size.

Metatarsal III is the longest of the series and decidedly more slender than metatarsal II. The shaft of this bone is constricted both laterally and antero-posteriorly, more especially in the latter diameter. The outer side of the bone is longer than the inner. The proximal end is subrectangular in outline with the greatest diameter in a fore and aft direction. The distal end is widest transversely with the median surface greatly hollowed out to accommodate the articulation of the proximal phalangial.

Metatarsal IV is slightly stouter than the preceding element, and of about the same proportions. The proximal articular end is subtriangular in outline. The distal end is subrectangular with a slight grooving of the median area. Just behind the distal part of the bone there is a shallow median depression as shown in A, fig. 27.

Metatarsal V which is missing in the present specimen may be distinguished from all of the others by its greatly expanded proximal and little enlarged distal end.

The manner in which the different elements of the metatarsus articulate at their proximal ends is clearly indicated in B, fig. 25.

Phalanges.—All of the phalanges of the left pes are present except the third small phalanx of digit III, the second of digit IV, and the vestigal proximal phalanx of digit V. These missing bones are present in the foot of a second specimen, No. 89 C. M.,[32] and are briefly described in order to make the description complete.

The first digit supports two phalanges. The proximal one is short and deep and articulates distally with the long, compressed, curved claw-like ungual. The proximal end of the first phalanx, see C, fig. 28, is slightly cupped, the distal end broadly grooved vertically. This end is cut off oblique to the longer axis of the bone, so that its articular surface looks somewhat outward. The large ungual of this foot lacks its anterior extremity, but as shown by the ungual of No. 89 C. M., it was obtusely pointed. The lower two-thirds of the articular end is shallowly concave dorso-ventrally, this surface being oblique to the longer axis of the bone, thus causing the ungual to be directed strongly outward when properly articulated. A decided longitudinal groove on its lower internal side, together with the pitted and roughened character of its surfaces, evidently indicates it to have been enveloped in life with a horny sheath which would have materially increased the size of this claw.

Digit II has three phalanges. The proximal is the largest of the entire first row. It is slightly longer than broad, with the inner side nearly perpendicular but the anterior surface slopes downward toward the outer side, which is relatively

[32]See Hatcher, Mem. Carnegie Museum, I, No. 1, 1901, fig. 22.

narrow and rounded. The inner side of the distal end is produced prominently forward thus giving this end a diagonal trend when viewed from above.

The second phalanx of this toe is reduced to a flattened wedge of bone, thickest on the internal side and compressed to an obtuse edge on the external side, see fig. 28. The terminal phalanx of this digit differs chiefly from the ungual of digit one in its smaller size.

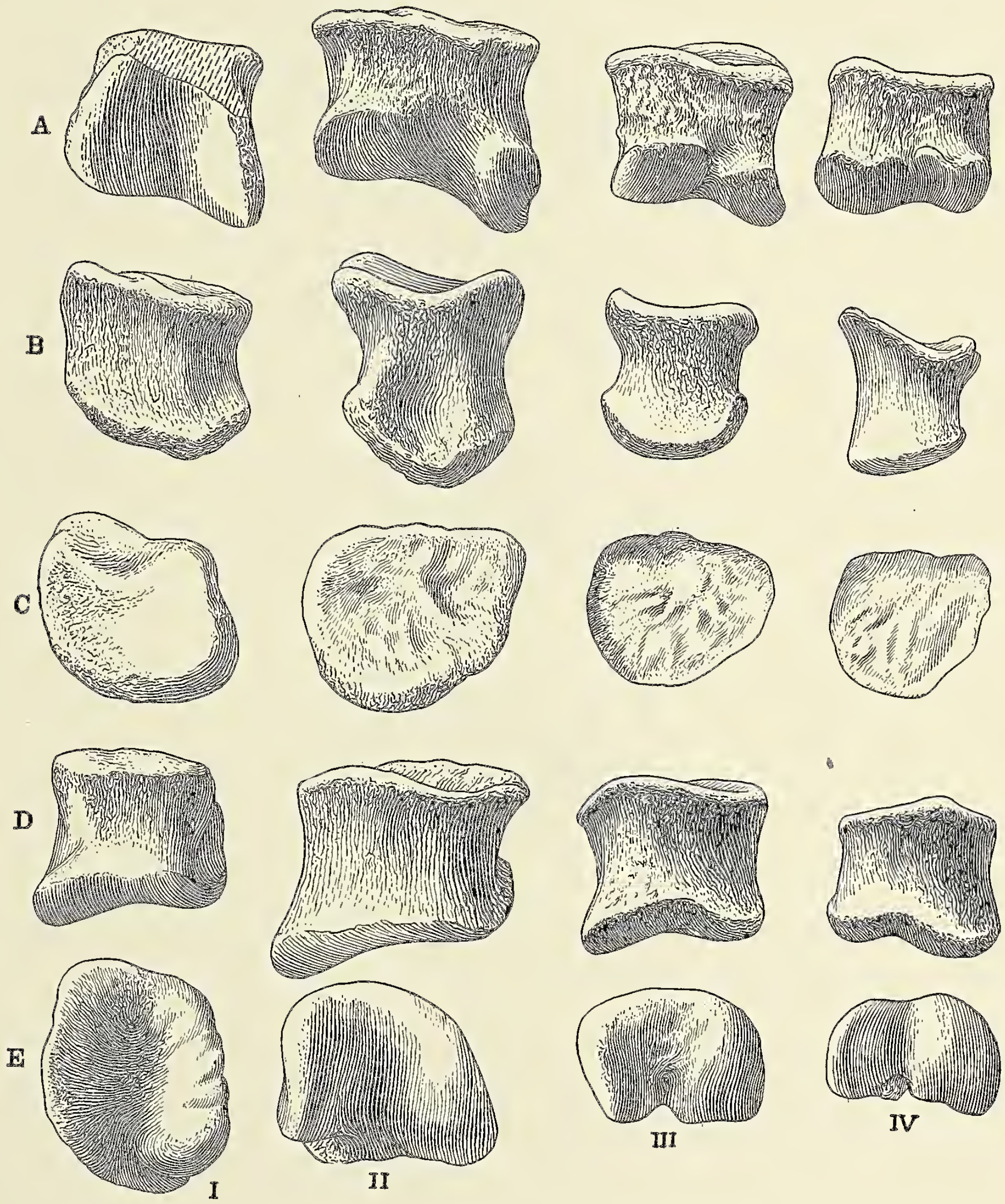

FIG. 28. Proximal row of phalangials of *Apatosaurus louisæ*. Type. 3018 C. M. *A.*, posterior views; *B.*, lateral views; *C.*, proximal views; *D.*, anterior views; *E.*, distal views., I, II, III, and IV, phalanges one, two, three, and four respectively. One-fourth natural size.

Digit III has four phalanges. The proximal is slightly longer than wide, with a concave proximal end and a shallowly grooved distal extremity. The second phalanx is a short, wedged-shaped bone that is thickest on the internal side. The third is missing in this specimen but in the complete pes of No. 89 C. M. it is a very short, ovately rounded, disk-like element. The ungual phalanx of digit III is hardly more than half the size of the claw on the first toe, but otherwise resembles it closely, see fig. 30.

A

B

C

D

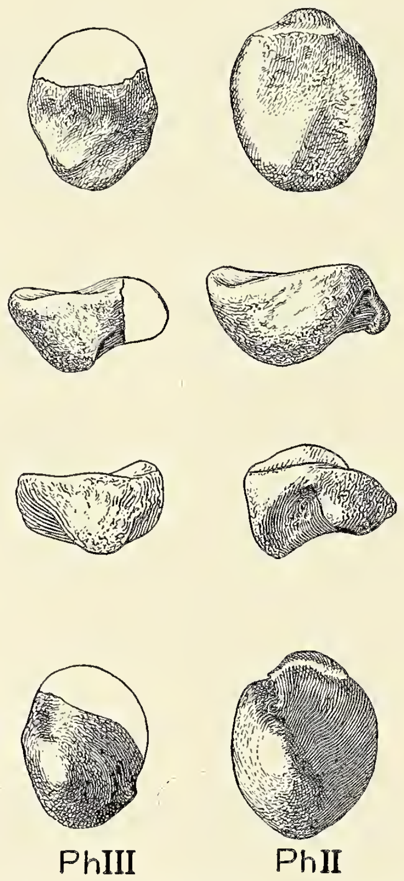

FIG. 29. Phalanges of left pes of *Apatosaurus louisæ*. Type. No. 3018 C. M. *A.*, proximal view; *B.*, lateral view; *C.*, dorsal view; *D.*, distal view. *Ph.II.*, second phalanx of digit II; *Ph.III.*, third phalanx of digit III. One-fourth natural size.

Digit IV has two phalanges. The proximal element is smaller than any of those previously described of the first row and may be distinguished from them by the fact that its longest side is external. Its principal features are clearly shown in fig. 28. The second phalanx of this toe, which is missing, is present in specimen No. 89 C. M. It is a vestigal, lozenge-shaped element having a slightly concave, thickened articular end, but is depressed anteriorly terminating in a transversely rounded obtuse border. This missing proximal phalanx of digit V is shown by

specimen No. 89 C. M. to be slightly smaller than the terminal of the fifth toe. Viewed from above it is subrectangular in outline but in other particulars resembles the terminal of digit IV. Both of these terminal bones were probably without a horny covering and may have been embedded entirely within the integument of the foot.

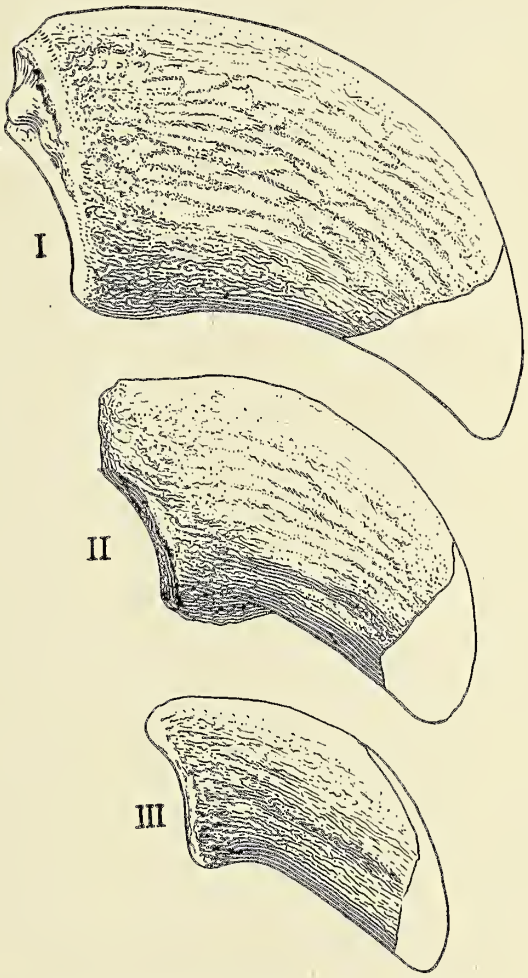

Fig. 30. Unguals of left pes of *Apatosaurus louisæ*. Type. No. 3018 C. M. Lateral views. I, II, III, unguals of digits I, II, and III respectively. One-fourth natural size.

The robustness of the elements comprising the inner side of the pes, apparently indicates that the main weight of the animal was borne by that portion of the foot. Digits IV and V were certainly undergoing atrophy as the phalanges of these outer toes are already functionally obsolete.

The principal dimensions of these various bones of the pes are given in the table of measurements below.

COMPARATIVE MEASUREMENTS OF METATARSALS

Metatarsals	Greatest length		Greatest transverse diameter proximal end		Greatest transverse diameter distal end		Greatest antero-posterior diameter of proximal end	
	No. 3018 C. M.	No. 89 C. M.	No. 3018 C. M.	No. 89 C. M.	No. 3018 C. M.	No. 89 C. M.	No. 3018 C. M.	No. 89 C. M.
	mm.	mm.	mm.	mm.	mm.	mm.	mm.	mm.
I	195	145	147	95	186	136	163	135
II	213	174	172	98	149	115	185	125
III	236	188	97	83	117	94	135	97
IV	238	201	153	119	115	94	101	93
V	...	192	...	144	...	69	...	60

COMPARATIVE MEASUREMENTS OF PHALANGES

Phalanges	Greatest Length		Greatest Breadth		Greatest Depth	
	No. 3018 C. M.	No. 89 C. M.	No. 3018 C. M.	No. 89 C. M.	No. 3018 C. M.	No. 89 C. M.
	mm.	mm.	mm.	mm.	mm.	mm.
Proximal phalanx digit I......	90	85	101	97	97	...
Proximal phalanx digit II.....	101	91	119	107	95	82
Proximal phalanx digit III.....	91	79	97	85	80	...
Proximal phalanx digit IV.....	82	70	92	79	75	48
Proximal phalanx digit V......	...	32	...	50	...	28
Second phalanx digit I (ungual)	248e	198	99	65	158	118
Second phalanx digit II.......	48	40	80	78	87	67
Second phalanx digit III......	43	75	77e	85	76e	...
Second phalanx digit IV.......	...	29	...	53	...	35e
Third phalanx digit II (ungual).	234e	167	70	62	128	99
Third phalanx digit III.......	...	17	...	41	...	31
Fourth phalanx digit III (ungual)	170	120	50	40	84	...

e = estimated.

THE MOUNTED SKELETON.

The skeleton of *Apatosaurus louisæ* is one of four mounted specimens of this genus now on exhibition in as many museums of this country. Named in the chronological order of their mounting these are in the Field Museum of Natural History, Chicago, 1903; the American Museum of Natural History, New York City, 1905; Carnegie Museum, Pittsburgh, 1913; and the Peabody Museum of Natural History, New Haven, Conn., 1930. In the matter of perfectness of preservation the present specimen is even more complete than the famous *Brontosaurus excelsus* skeleton in the Peabody Museum of Natural History of New Haven. In size there is little choice between them as all are large adult animals.

The Carnegie Museum specimen has been mounted in an upright quadrupedal pose, and, standing in the exhibition hall alongside the well known *Diplodocus carnegii* skeleton of slenderer proportions, it forms an association that serves to emphasize its ponderous size and massiveness of structure, see Pl. XXXV.

The preparation and mounting of this skeleton was done under the direction of Mr. Arthur Coggeshall, assisted by Messrs. Louis Coggeshall and Albert Moorehouse. This work was accomplished in three years, a record so far as time is concerned.

The vertebral column is supported by a linear series of steel castings that closely conform to the undulating shape of the underside of the vertebræ, and these castings in turn are supported at the required height by heavy pipe standards securely anchored in the base. The sections of vertebral castings after having been placed in position were welded together to form a continuous whole. This method, first devised and used by Mr. Coggeshall in mounting the skeleton of *Diplodocus*, was much improved on the present specimen in being made much lighter in construction and in more closely adapting it to the shape of the bones. The limbs and other bones are held in position by half-round iron bars having the flat sides fitted closely to the inequalities of the bones. By these means the heavy parts of the skeleton are held in their proper articulated positions, and so skillfully has this work been done that the observer is hardly aware of the supporting framework. With the skull in position the specimen has a total length between perpendiculars of about 71 feet and 6 inches. If the missing eighteen terminal caudal vertebræ were added to the tip of the tail, in order to make it conform to known evidence, the skeleton will reach an estimated length of 76 feet, 6 inches. The highest point, at the tops of the spinous processes of the anterior sacrals, is 14 feet, 8 inches, above the base.

In preparing the specimen, all missing parts of the vertebræ were restored and distortions were corrected. The three posterior cervicals, Nos. 13, 14, and 15, however, were so badly crushed out of shape that it was not deemed expedient to correct them and they have been replaced in the skeleton by replicas, and the originals in their distorted condition were placed in storage. Likewise the sixteenth caudal vertebra, so far as I could make out, is entirely restored but Mr. Louis Coggeshall assures me that core parts of the vertebral centrum are present but have been covered in restoring it to the proper form.

One of the striking features brought out by this skeleton, through the articulation of the bones, is the prolonged elevation of the anterior caudal region as it extends backward from the sacrum before beginning its drop toward the ground. In my opinion this feature would have been more emphasized had the first caudal

been fully articulated. As it stands the centrum of this caudal is farther away from the last sacral centrum at the top than at the bottom and the zygapophyses are not fully engaged. Had these bones been fully articulated the tail would have had more of an upper arctuation and this part of the animal would have been in full accord with the more recently mounted skeleton of *Diplodocus* in the United States National Museum. It is fast becoming obvious that all Sauropodous dinosaurs, when properly posed, have this lizard-like upward curve of the anterior caudal region.

Close inspection of the dorsal segment of the vertebral column clearly shows these vertebræ to have been too widely spaced thus giving undue length to the thoracic region. The scapula should also be drawn inward closer to the ribs, but with these few critical remarks, I wish to observe that the skeleton as a whole is well posed and well articulated in the light of our present knowledge of these animals.

In the mounted skeleton the fore feet were provided with restored unguals on digits II and III and a full complement of phalangials. The negative evidence drawn from several articulated Sauropod fore feet indicates a reduction in the number of phalangials and unguals and in the illustration of the skeleton, see Plate XXXIV, these extra bones have been omitted.

RESTORATION OF THE SKELETON

The restoration of the skeleton of *Apatosaurus louisæ,* see Plate XXXIV, is based primarily on the mounted skeleton in the Carnegie Museum. The illustration was drawn with the greatest care by Mr. Sydney Prentice, from orthographic projection drawings of each bone made separately and then assembled in the figure as a whole, after the pose of the mounted skeleton. Missing parts of bones are indicated by distinctive shading. Missing bones in a few instances have been drawn with certain modifications from the evidence furnished by other specimens of this genus. Distortions were corrected at the time of preparing the skeleton so few corrections were necessary by the draughtsman. About the only structural details of *Apatosaurus,* which may be considered unknown at the present time are the skull, lower jaws, and the successional changes and total number of the chevron bones.

As shown in previous restorations of this animal, the shortness of the thoracic region as contrasted with its other vertebral proportions is most striking. The extension of the tail into an extraordinarily attenuated "whip lash" is the outstanding contribution of the present restoration, where the tail is illustrated in its entirety for the first time.

The restoration embodies all of the latest information concerning the skeletal

structure of *Apatosaurus*, and with the exception of some slight errors of articulation due to having closely copied the position of the bones in the mounted skeleton, already commented on in previous pages, it is believed to be the most faithful presentation of the skeleton of this animal yet attempted.

The first skeletal restoration[33] of *Apatosaurus* (*Brontosaurus*) was made under the direction of Professor O. C. Marsh in 1883, and in most respects it was more nearly correct than his emended restoration which appeared eight years later.[34] Three additional posterior dorsal vertebræ, a lumbar and two cervicals, were added to the vertebral column, and the number of ribs was increased from eighteen to twenty-six. The crest of the dorsal arch was carried forward nearly to the midlength of the thoracic region. As is now known, with the exception of the added cervicals, all of the other changes were in error. Riggs[35] was the first to call attention to these mistakes and in the same paper presented a third restoration based upon a partial skeleton in the Field Museum of Natural History, which for the first time showed the correct number of dorsal vertebræ.

The gradual evolution of our knowledge concerning the structure of the vertebral column in *Apatosaurus* is clearly set forth in the table below.

	Restoration No. 1 Marsh 1883	Restoration No. 2 Marsh 1891	Restoration Riggs 1903	Restoration *A. louisæ* 1934
Number of cervicals	11	13	13	15
Number of dorsals	9	13	10	10
Number of lumbars	1	1	0	0
Number of caudals	51	49	46	84

The crest of the dorsal arch stands just in front of the sacrals, as first determined by Riggs.

PARTIAL DESCRIPTION OF A SKELETON OF *APATOSAURUS EXCELSUS* (MARSH)

Brontosaurus Hatcher, J. B., Science, N.S. vol. XIV, No. 365, 1901, pp. 1015-1017; Ann. Carnegie Museum, vol. I, 1902, pp. 356-376, pls. 19-22, 14 text figs.

A second specimen of *Apatosaurus*, No. 563 C. M., furnished much supplemental information regarding the skeletal structure of this genus, and as a large number of illustrations were already prepared it was decided to include them with appropriate text in the present paper. Most of these illustrations were made more than thirty years ago by Mr. Sydney Prentice under the direction of the late Mr. J. B. Hatcher. Since the skeletal parts of *Apatosaurus louisæ* have been described

[33]Marsh, O. C., Amer. Jour. Sci., XXVI, 1883, Pl. I.
[34]Marsh, O. C., Amer. Jour. Sci., XLI, 1891, Pl. XVI.
[35]Riggs, E. S., Field Columb. Mus., Pub. 84, Geol. Ser. 1903, Pt. I, p. 195, Pl. LIII.

in detail it appears only necessary with the present specimen to call attention to such differences as are found to exist between homologous bones of the two species, and to describe in detail only those elements which either were not well preserved or were entirely absent in the *A. louisæ* skeleton.

Specimen No. 563 C. M., was collected by the writer in 1901 for the Carnegie Museum from the Morrison formation, about one mile south of Sheep Creek, Albany County, Wyoming. It was found about a quarter of a mile west of "Quarry D" which yielded the two skeletons, Nos. 84 and 94 C. M. of *Diplodocus carnegii*, but from thirty to forty feet lower in the formation. The specimen for the most part was found disarticulated, but isolated, there being no duplication of bones except for the presence of the small type specimen of *Elosaurus parvus* [36] and a few bones of *Pleurocoelus*[37] which came out of this same excavation. This specimen was identified by Hatcher[38] as pertaining to the genus *Brontosaurus* = (*Apatosaurus*), an identification verified by this more detailed study. An itemized list shows the following bones to be preserved: 9 cervical, 9 dorsal, 5 sacral and 18 caudal vertebræ, left ilium, both pubes, both ischia, many ribs; 3 chevrons, left scapula and coracoid, both humeri, both radii, both ulnæ, and complete right manus, scapho-lunar, right femur, both tibiæ, fibula and astragalus, 1 ungual and a few scattered foot bones.

Cervical vertebræ.—There are nine cervical vertebræ preserved, all but the two posterior ones being essentially complete. Comparison of these with the articulated series of *A. louisæ* appears to indicate that they represent an interrupted series from the third to the tenth inclusive. The remaining two are so fragmentary that a determination of their precise position in the neck is uncertain. They are tentatively regarded as being the 13th and 15th as shown in Plate XXXI.

The centra are slightly shorter than the corresponding elements of the *A. louisæ* neck and are as a whole bulkier. The capitular processes are relatively shorter and stouter than in the cervicals of *Apatosaurus louisæ.* The single spines of the third, fourth, and fifth cervicals are preserved intact; these which are missing in *A. louisæ,* show that bifurcation of the spinous processes in *Apatosaurus* begins posterior to the fifth cervical. There is no indication of a notch on the top of the spine of C 5, this end being almost squarely truncate, as shown in Plate XXXI.

The variations found in the arrangement of the laminæ and pleurocœls in the homologous vertebræ of Nos. 563 and 3018 C. M., respectively, are not much greater than is often found on opposite sides of a single vertebra.

The infrapostzygapophysial cavity in this specimen posterior to the fifth

[36]Peterson, O. A. and Gilmore, C. W., Ann. Carnegie Mus., vol. 1, 1902, pp. 490-499.

[37]Hatcher, J. B., Ann. Carnegie Mus., vol. 2, 1903, pp. 9-14.

[38]Hatcher, J. B., Ann. Carnegie Mus., vol. 1, 1902, Pt. XIII, p. 356.

vertebra is consistently subdivided by an oblique accessory lamina which connects the infrapostdiapophysial with the horizontal lamina, whereas in the cervicals of *A. louisæ* this cavity remains undivided throughout the series. The median notch at the base of the metapophyses is usually wider in the cervicals of *A. louisæ*. The measurements of these vertebræ will be found in the table of comparative measurements on page 196.

Dorsal vertebræ.—Nine dorsal vertebræ are preserved with specimen No. 563 C. M., six of which lack their spinous processes. These vertebræ, although found disarticulated, are regarded as forming a continuous series from the first to the ninth inclusive. Comparison with the dorsal series of *A. louisæ* shows some decided differences in their structural details and if these features can be relied upon as being constant, they furnish characters indicating their specific distinction. The constancy of these features, however, can only be determined by a comparison of a greater number of individual specimens than have been available to me.

The most conspicuous differences are found in the centra, pleurocentral cavities, neural spines, and placement of the capitular facets and hyposphene. The various lamina also show considerable variation in the two series, but since the lamina are often unlike on the opposite sides of a single vertebra, the variations found are not considered as important as those differences observed in the other vertebral structures previously mentioned.

The centra of D 1, D 2, and D 3, are strongly opisthocœlus. D 1, as in the Field Museum specimen, has the longest centrum of the dorsal series. In the type of *A. louisæ* it is shorter than D 2. The pleurocentral cavities of the anterior dorsals are quite different in the two specimens. In D 1, of *A. louisæ*, the pleurocentral cavity is the smallest of the entire dorsal series and situated at mid-height and on the posterior half of the centrum. In D 1, of No. 563 C. M., this cavity is large, situated at mid-height but about equally spaced between the two ends of the centrum. In D 2, the cavity is reduced in size but located similar to D 1. D 3 has the smallest pleurocentral cavity of the series, situated slightly above the mid-height of the centrum. In *A. louisæ* these cavities increase in size from D 1 to D 3, accompanied by a progressive elevation upward on the side of the centrum. Throughout the rest of the dorsal series the pleurocentral cavities are subequal in size and similarly located near the top of the centra. Centrally placed antero-posteriorly, from D 4, posteriorly they move forward in the posterior members of the series, and are closer to the anterior than to the posterior end.

The neural spines or metapophyses on the anterior dorsals vary somewhat in the depth of the median division of the spines in homologous vertebra of the two specimens, being relatively deeper in specimen No. 563 C. M. In this speci-

men the bottoms of these notches are narrow whereas in the *A. louisæ* vertebræ they are widely U-shaped. Compare Pls. XXV and XXXII. That this narrowness of the bottom of the notch separating the metapophyses is not a constant character in *A. excelsus* is indicated in the Field Museum specimen by wide notches on D 3 and D 4.

The capitular facets, on D 1 of No. 563 C. M., are situated anterior to the pleurocentral cavity and slightly below the mid-height of the centrum; on D 2, they are much enlarged vertically but occupy practically the same position; on D 3, they are still on the sides of the centrum but near the top; on D 4, they have shifted to a position above the mid-height of the neural arch. These changes in position of the capitular facets in the anterior dorsals are in accord with the conditions found in the type of *A.* (*Brontosaurus*) *excelsus*, and in the Field Museum specimen of *Apatosaurus*. In *A. louisæ*, however, these facets are on the sides of the centra in D 1, and D 2, but in D 3, the facet is high on the arch as in D 4, of specimen No. 563 C. M.

Corresponding with this delayed upward shifting of the capitular facets, it is found that the hyposphene-hypantrum articulation first appears on D 4, whereas in *A. louisæ* it first occurs in D 3. In specimen No. 563 C. M., the hyposphene reaches its strongest development on D 6, but gradually diminishes in size posteriorly so that on D 9 it persists as scarcely more than a thin vertical bar of little or no function. Throughout, the dorsals having this type of articulation are more robustly developed than the corresponding elements of the *A. louisæ* skeleton. In the Field Museum specimen, Riggs[39] notes that the hyposphene reaches its strongest development on D 4 as in *A. louisæ*. In No. 563 C. M., within the area of strongest development the hyposphene is supported from below by a pair of strong buttresses that arise from the arch on a level with the top of the neural canal. Similar buttresses are present in the Field Museum specimen but are entirely absent on the dorsals of *A. louisæ*.

The centra of the posterior dorsals are subelliptical in outline, the transverse diameter considerably exceeding the vertical, whereas the same dorsals in the *A. louisæ* skeleton have these diameters subequal. The transverse processes throughout the dorsal series are more robustly developed, see Pl. XXXII, than in *A. louisæ*, the most pronounced difference in this respect being found in D 3. Comparison of these two series of dorsals shows that the dorsals of *A. excelsus* are stouter, more compact, and more fully braced by supporting lamina, than in *A. louisæ*.

Sacral vertebræ.—In specimen No. 563 C. M., the sacrum is composed of five vertebræ coalesced by their centra. The primary sacrum in the Sauropoda consists

[39]Riggs, E. S., Field Columb. Mus., Pub. No. 82, Geol. Ser., No. 4, 1903, p. 175.

of three vertebræ to which has been added a posterior dorsal (sacrodorsal) and an anterior caudal (sacrocaudal), but in the present description all will be referred to as sacrals.

In addition to the coalescence of the vertebral centra their union is further strengthened by the coössification of their zygapophyses, neural arches, and bases of their diapophyses. In this specimen the spines of S 2 and S 3 are fused for their entire length, but in the type of the species and in the Field Museum specimen, both slightly larger individuals, the spines of S 2, S 3, and S 4, are thus co-joined. In the type of *A. minimus* (No. 675 A.M.N.H.)[40] however, the spine of S 5 is also coössified with the others. Thus in *Apatosaurus* there are from two to four spines coalesced in the sacrum. Although the evidence at hand may indicate this feature to be a specific difference, I am inclined to the opinion that it will not prove to be constant, varying with and perhaps influenced by the age of the individual.

At least eight sacra of *Apatosaurus* are now available for comparison and these apparently show, as first pointed out by Riggs,[41] that the number of coalesced sacrals is largely determined by the age of the individual. In *Apatosaurus* it now seems definitely established that the normal number is five co-joined vertebræ, although an occasional individual may show an additional dorsal or caudal thus coössified.

The neural spines decrease regularly in height from front to back. The spine of S 4 is entirely missing in this specimen but that it stood free as those of S 1 and S 5 is indicated by the absence of a sutural surface on the posterior border of the spine of S 3. Supradiapophysial laminæ give lateral support to the spines, those of S 2 being especially robust in character. The transverse axis of the sacrum passes through S 3, and it is of interest to observe that the diapophysial processes are so arranged as to brace and strengthen this portion of the skeleton against the fore and aft stresses placed upon it. Reference is made to the divergent ray-like arrangement of the diapophysial processes when viewed from above, see figs. 31 and 36. The processes of S 1 and S 2 are directed forward and outward, and those of S 3, S 4, and S 5, are directed backward and outward. In the present articulated condition it is impossible to properly study the structural arrangement of the sacral ribs and their attachments and on that account their description is omitted.

Sacral five as shown in fig. 31 is attached to ilia by broad transverse processes but no trace of its division into diapophysis and sacral rib is to be observed.

The height of the postzygapophyses, see fig. 31, which looks almost directly downward, above the level of the neural canal in *S 5* would seem to indicate that the caudal identified as *C 1* might be *C 2* and that the first is missing in this speci-

[40]Mook, C. C., Bull. Amer. Mus. Nat. Hist., XXXVII, 1917, fig. 1c.

[41]Riggs, E. S., Field Columb. Mus., Pub. No. 82, Geol. Ser., 1903, p. 182.

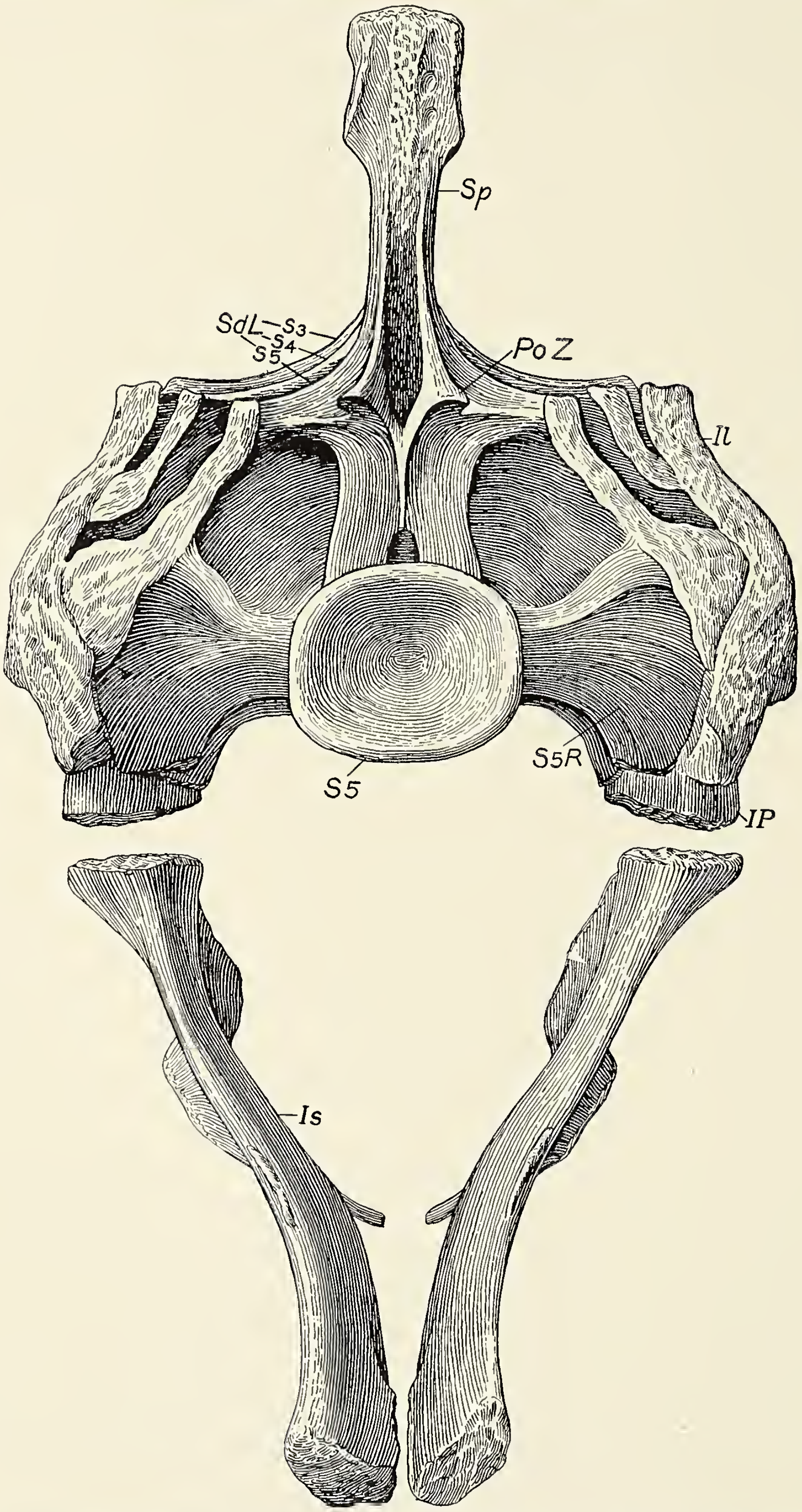

Fig. 31. Pelvis and sacrum of *Apatosaurus excelsus* No. 563 C. M. Posterior view. *Sd L. 3, 4, 5*, supradiapophysial laminæ of sacrals 3, 4, and 5 respectively; *il.*, ilium; *i.p.*, ischiac peduncle; *is.*, ischium; *po.z.*, postzygapophyses; *s 5.*, sacral five; *s 5R.*, fifth sacral rib; *sp.*, spine of fifth sacral. Right ilium restored from the left side. One-tenth natural size.

men. The zygapophyses are braced from above by the strong suprapostzygapophysial laminæ which merge into the posterior face of the spine above its mid-height. The principal features of the posterior view of S 5 are well shown in fig. 31.

The sacriocostal yoke is formed by the coalesced distal rib articulations of the first four sacrals, to which the lower part of the transverse process of S 5 is also attached. The inferior surface of this yoke contributes to the formation of the acetabulum. These ribs unite with nearly the whole length of the sacral centra as in the type of *A. excelsus.*

MEASUREMENTS OF SACRAL VERTEBRÆ

Greatest length of five coössified centra	1183 mm.
Height of coalesced spines	543 mm.
Fore and aft diameter of two coalesced spines at summit	303 mm.
Greatest height over all of S 1	1085 mm.
Greatest height over all of S 5	980 mm.
Greatest expanse of transverse processes of S 5	804 mm.

Caudal vertebræ.—Eighteen caudal vertebræ are preserved with specimen No. 563 C. M. All of these were found disarticulated, but by comparison with the articulated caudal vertebræ of *A. louisæ* they have been allocated in series as shown in Plate XXXIII. Eleven of the eighteen elements have transverse processes, thus indicating their anterior position in the tail. Study of their principal dimensions, as shown in the table of measurements p. 210, seems to indicate that they represent a continuous series from the first to the ninth inclusive. In the type of *A. excelsus,* as in the Field Museum *Apatosaurus,* twelve of the caudals bear transverse processes. The American Museum specimen has but eleven, whereas the type of *A. louisæ,* and No. 3378 C. M. both show fourteen. From this evidence it is quite apparent, that any mistake made in the allocation of these scattered elements, cannot be very seriously in error. The remaining nine, however, cannot be so certainly placed and their allocation should be considered tentative.

Viewed from the end the centra of these anterior vertebræ are all subequal in transverse and vertical diameters, in this respect differing from the anterior caudals of *A. louisæ* which has the vertical exceeding the transverse diameter. The lengths of the centra are relatively shorter, and there is no indication of a ball on the posterior end of C 1, and it is only slightly indicated on C 2, and C 3.

The first and third caudal vertebrae of this specimen are completely preserved and these apparently indicate that there is a more rapid shortening posteriorly of the spinous processes than has been indicated in the restoration of the missing spine tops in the mounted skeleton of *A. louisæ,* consequently in this respect the present restoration, plate XXXIV, is probably slightly in error.

The first caudal in *Apatosaurus* has a number of characteristics which distinguish it from the other vertebræ of the caudal series. The most outstanding is the great plate-like development of the transverse processes. These spring from the sides of the upper half of the centrum and the neural arch, and extend directly outward on a level with the postzygapophyses terminating in a slightly expanded end that is nearly vertical in this specimen. These processes rapidly decrease in vertical extent posteriorly, and posterior to C 1, have their outer ends beveled off from above downwards. In the first three caudals these processes are perforated by a large foramen-like opening on either side of the neural arch.

In C 3, however, these perforations do not pass entirely through the bone. Practically similar conditions obtain in the type of *A. excelsus*. That these foramina are not always present in individuals of this species is shown by their absence[42] in C 1, of the Field Museum specimen. They are not present in any of the caudals of *A. louisæ*. Holland has used this feature as one of the characteristics for distinguishing *A. excelsus* from *A. louisæ* but in view of their variable character, it would seem not to be of importance in that connection.

Cervical ribs.—Cervical ribs are present on all of the vertebræ and except the fifteenth pair all are anchylosed by their tubercular processes to the diapophyses, and by their capitular processes to the parapophyses. The fifteenth pair are to be recognized by their non-coalescence with the vertebra, see pl. XXXI, their short fore and aft diameter and broadly curved border between the tubercular and capitular processes. In most of the cervicals the tubercular process extends downward and slightly outward from the diapophysis and thus increases the width of the vertebra. The ribs have anterior and posterior branches that usually parallel the centrum, but in none of those present does the rib exceed the centrum in length. These ribs differ from those of *A. louisæ* in having a blunt extension that projects forward of the line of the tubercular process, whereas in *A. louisæ*, this end is smoothly rounded but with a heavy node-like projection that projects downward and outward.

Scapula and coracoid.—The left scapula with a portion of the coössified coracoid is present in this specimen, as shown in fig. 32. In so far as it can be compared with the complete scapula of the type of *A. excelsus*, the two bones are in the closest accord, compare fig. 32 with *C*, fig. 10. From the scapula of *A. louisæ* this bone may be distinguished by the backward inclination of the posterior border near the distal end, by the right-angled trend of the transverse ridge or spine and the increased area of the muscular fossa above this ridge. On account of the close resemblances to the typical *A. excelsus* scapula it is presumed that the missing

[42]loc. cit., Pl. XLVI, fig. XII.

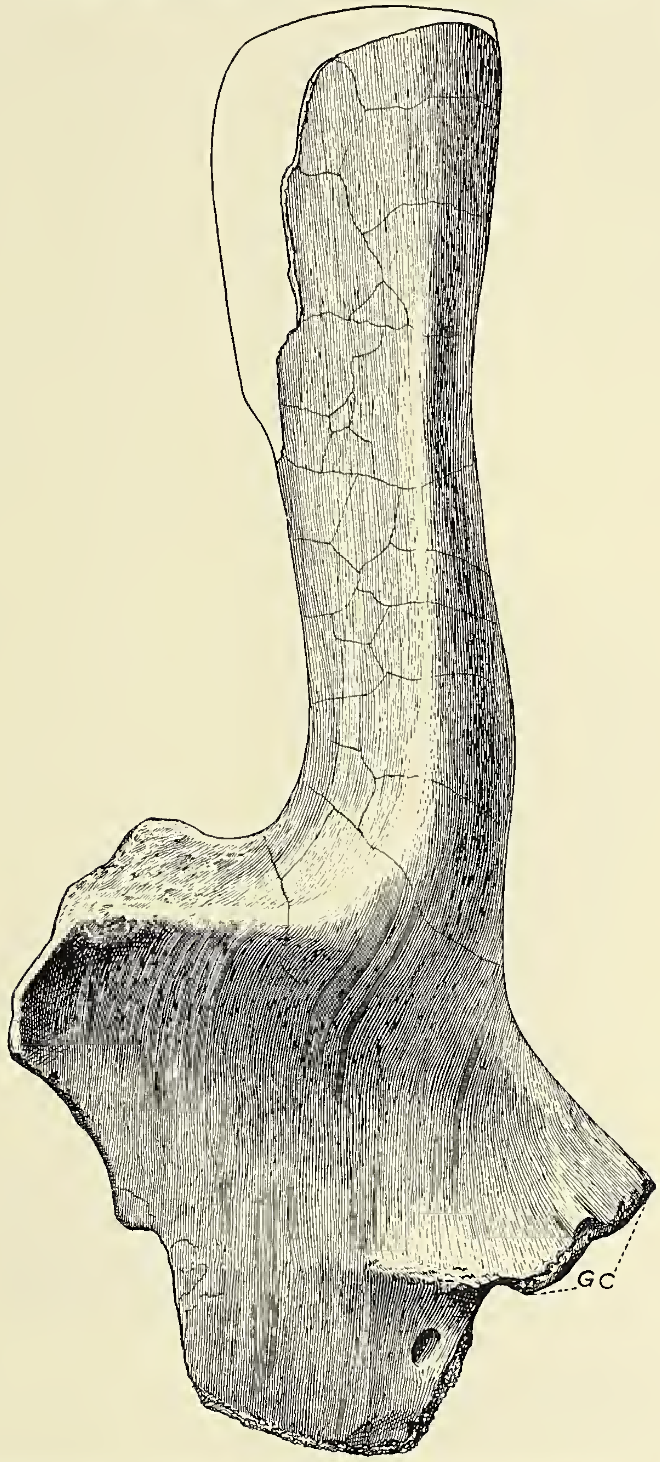

FIG. 32. Left scapula and portion of coracoid of *Apatosaurus excelsus*, No. 563 C. M. Lateral view. *G.C.*, glenoid border. One-tenth natural size.

anterior border of the upper portion of the blade had a forward expansion and it has been thus restored. The measurements of this bone will be found on page 216.

The coracoid is too incomplete to offer any basis of comparison.

"*Humerus.*—[43]The shaft of this bone is much constricted, while the extremities are greatly expanded transversely, the proximal to a much greater extent than the distal. There is a very prominent deltoid ridge extending along the anterior external border from the proximal and throughout one-half the length of the bone. Between the ridge and the inner margin there is on the anterior surface a rather deep basin, subtriangular in outline, bounded above by the anterior border of the slightly thickened broad proximal end and externally and internally by the deltoid ridge and internal lateral margins, which converge inferiorly where the shaft becomes much restricted. The proximal end has the transverse diameter much expanded while the fore and aft is quite short. In the present specimen the differences between these two diameters is somewhat magnified through distortion due to crushing. Superiorly the proximal end is regularly convex, so that when seen

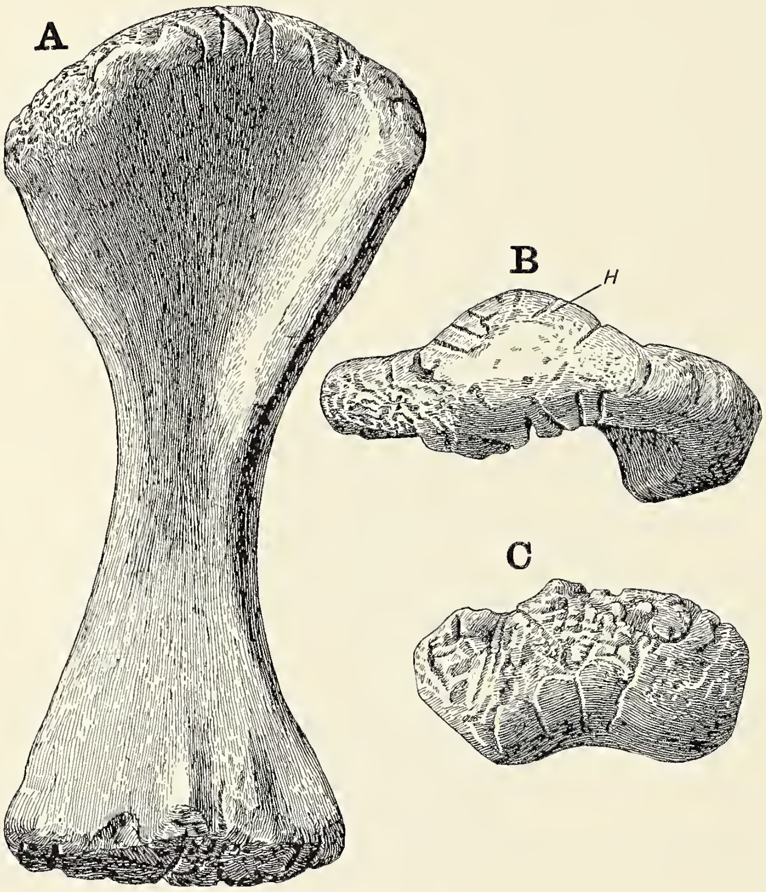

Fig. 33. Right humerus of *Apatosaurus excelsus*, No. 563 C. M. *A.*, front view; *B.*, proximal end; *C.*, distal end; *H.*, head. One-tenth natural size. (New figures)

[43]The right fore limb and foot of specimen No. 563 C. M. has been described in detail by Hatcher (Annals Carnegie Museum, I, 1902, pp. 360-373) and with the exception of some omissions of references to figures and plates and tables of measurements) the description is repeated here in its entirety.

from behind or in front its upper border describes an almost perfect arc, the chord of which in the present specimen has a length of 600 mm. The head is placed about midway between the external and internal borders, but a little nearer to the latter, and is directed rather strongly backward much as in the Testudinata. It is very rugose, only moderately expanded in either direction."

"Distally the transverse diameter of the humerus is about double the fore and aft. The articular surface is exceedingly rugose and deeply pitted as though covered in life with heavy cartilaginous epiphyses which never became thoroughly ossified and through the intermedium of which it articulated with the radius and ulna. On the posterior border there is an emargination indicative of an anconeal fossa. This is extended into the articular area in such manner as to cause a slight median constriction on the posterior side directly opposite a slight anterior expansion on the anterior surface. There is a small and imperfectly defined external condyle. The posterior border of the humerus is regularly convex transversely throughout most of its length, though much flattened proximally and slightly grooved distally."

"*The Radius and Ulna.*—These bones are subequal in size. The distal third of the ulna is a little more slender than the same portion of the radius. The shaft of the radius is constricted medially while the ends are about equally expanded. The proximal end is semi-circular in cross-section, the convex surface fitting nicely into the radial groove on the anterior surface of the proximal end of the ulna. Proximally the radius articulates only with the anterior and internal portion of the distal articular surface of the humerus. The proximal end of the ulna entirely encloses that of the radius posteriorly and externally so that its articular surface is opposed to that of the distal end of the humerus posteriorly throughout its entire breadth, while at the same time presenting a broad and deep articular surface on the anterior projection which encloses the radius externally for contact with that of the anterior and external surface of the humerus. The contact of the radius with the humerus is thus limited to the antero-internal surface of the humerus instead of the antero-external as determined by Osborn and Granger,[44] so that these bones are not so completely crossed as these authors had supposed, but occupy positions almost identical with those figured by the late Professor Marsh as obtaining in the fore limb of *Morosaurus*.[45] Seen from above the proximal end of the ulna may best be described as tri-radiate. The rays are formed by the posterior anconeal spine, the directly opposite external anterior projection and the widely expanded internal portion. The first two of these are subequal and much smaller than the last. All are separated by concave surfaces. There is a deep cavity on the posterior

[44]Bull. Am. Mus. Nat. Hist., vol. XIV, pp. 199-208.

[45]Part I, Sixteenth Ann. Report U. S. Geol. Survey, pp. 143, 244, Plate XXXVII.

surface between the anconeal spine and the internal, lateral margin of the ulna. Distally the radius shows a prominent rugosity on the posterior side near the external border. This commences about four inches from the distal extremity and continues as a prominent narrow ridge for a distance of nine inches. At about one-third the distance from the lower to the upper end of this rugosity it is interrupted by a deep groove which starts on the inner side, runs obliquely downward and outward, completely bisecting the rugosity. This groove doubtless served for

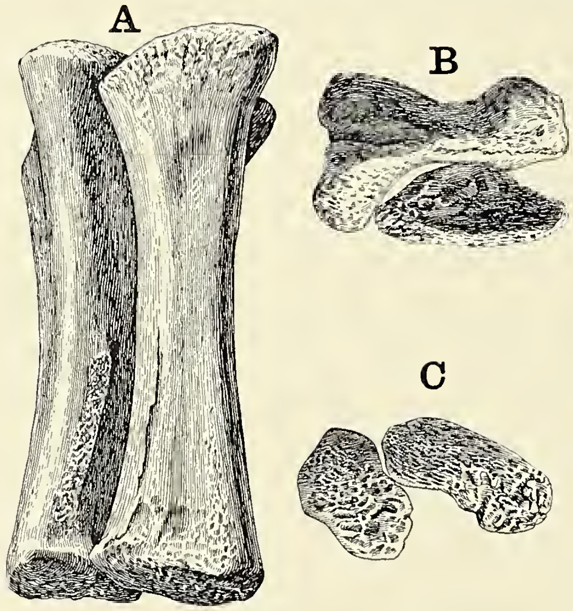

FIG. 34. Right radius and ulna, articulated, of *Apatosaurus excelsus*. No. 563 C. M. *A.*, front view; *B.*, view of proximal ends; *C.*, view of distal ends. One-tenth natural size. (New figures)

the transmission of an artery. Opposed to this rugosity on the radius there is a similar one on the middle of the internal surface of the ulna near its distal extremity. These rugosities doubtless served for the attachment of the muscles which held these bones in place. Seen from below, the articular surface of the distal end of the radius has the form of an elongated ellipse with an area somewhat exceeding that of the distal end of the ulna, which takes the form of an oblique quadrangle with its two axes nearly equal. There is, on the internal surface of the distal end of the ulna, a rather deep emargination or fossa for the reception of the rounded postero-external angle of the distal end of the radius. This emargination appears, though less distinctly, on the internal border of the distal articular surface of the ulna. Its presence affords great assistance in the proper adjustment of these bones, since, when they are so placed that the convex surface of the proximal end of the radius fits nicely into the radial groove of the ulna and the postero-external angle of the distal end of the radius in this fossa, there can be no question as to the

correct relative positions of these bones. The articular surfaces of the distal ends of the radius and ulna display different degrees of rugosity. The postero-internal portions of each are extremely rugose and deeply pitted, while toward the center the surfaces become less indented and the external half of each presents a polished surface marked with shallow corrugations."

"*The Carpus.*—There was but one carpal bone found with the present limb and foot. This agrees very closely with the description given by Osborn and Granger of the supposed scapho-lunar in *Diplodocus,* and with those authors I agree in making it homologous with that element in the mammalian carpus. If my interpretation of the position of this bone in the manus is correct the following description of this element would apply. The general form is that of a circular disc, thin in front but considerably thickened posteriorly. The superior surface is crossed antero-posteriorly by a low, broad ridge which divides it into two slightly concave and subequal surfaces, the larger and smoother of which was for articulation with the external half of the distal end of the radius, while the smaller and more rugose

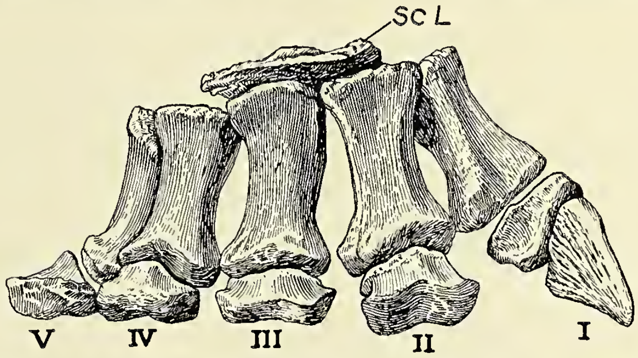

FIG. 35. Right fore-foot of *Apatosaurus excelsus,* No. 563 C. M. Viewed from the front. *ScL.,* scapho-lunar; I, II, III, IV, V, digits one to five respectively. About one-ninth natural size. (New figure)

surface articulated with the internal portion of the distal articular surface of the ulna. Inferiorly this bone presents a gentle convex, polished, but corrugated surface for articulation with metacarpals II, III, and IV. No other carpals were found with or near this foot, and after a careful study of it and the articular surfaces of the distal ends of the radius and ulna and considering the position in which metacarpals II, III, and IV lay with reference to these bones and metacarpals I and V, it appears quite probable that it was the only ossified element present in the carpus of *Brontosaurus* and therefore that the Brontosaur carpus, like the tarsus, consisted of a single element."

"*The Metacarpals.*—All the elements of the metacarpus were present and in approximately their normal positions when the foot was uncovered."

"Metacarpal I is short and much the strongest bone of the entire series. The

proximal end is very deep, but much compressed. The articular surface is gently concave vertically and convex transversely. The internal lateral margin of the proximal end is regularly convex so that this margin and the proximal articular surface as well conform to the internal margin and internal articular surface of the radius with which during the life of the animal it probably had a direct, cartilaginous articulation. The external lateral margin of the proximal end is regularly concave and just in front of the articular surface there is a deep cavity for the reception of a corresponding prominence on the internal margin of metacarpal II. The external surface is rugose throughout the entire length of the bone; it is much constricted vertically in the middle, but with decided distal and proximal expansion for contact with metacarpal II. The internal lateral surface is regularly but gently convex vertically throughout the entire length of the bone and only slightly constricted vertically in the middle region. The superior surface gradually broadens from the proximal to the distal end. The inferior surface is deeply concave longitudinally, broad at the distal extremity, but reduced to a sharp narrow ridge at the proximal end. The distal articular surface has the vertical and transverse diameters subequal. It is continued well back on the palmar side of the bone in order to accommodate the thin sheet of bone which projects posteriorly from the palmar side of its proximal phalanx. There is a vertical, median groove for the accommodation of the low median keel of the latter."

"Metacarpal II is longer and more slender than the preceding, although decidedly stronger than metacarpal III. It is somewhat constricted medially both in its vertical and lateral diameters. Compared with metacarpal I it is broad, but greatly depressed. The superior as well as the distal portions of the lateral surfaces are smooth, while the inferior and proximal portions of the lateral surfaces are covered with rugosities. The inferior internal angle of the proximal end of this bone is especially modified as so to fit nicely into the deep cavity just described as present on the external lateral surface of metacarpal I. These bones are so interlocked that when placed in position a considerable portion of the proximal end of mc. II is covered over by the superior border of the cavity in mc. I, while the proximal end of the latter is raised above that of mc. II, so as to articulate directly with the radius. There is a broad, shallow excavation on the external lateral surface at the proximal end of mc. II for the reception of the internal proximal angle of mc. III. The proximal articular surface of mc. II is broad above and somewhat narrowed inferiorly. Its superior and inferior margins are bounded by nearly straight, horizontal lines. The surface is very slightly and regularly convex in all directions. The distal articular surface is broad and deep, though in the present specimen the latter diameter has been somewhat diminished by pressure.

Just anterior to the rugosity on the internal lateral surface of the proximal end of this bone there is a deep groove leading obliquely downward and forward to the palmar surface. This may have served for the transmission of a flexor tendon."

"Metacarpal III is of equal length, but decidedly more slender than mc. II. The superior surface is smooth and regularly convex. There is a noticeable lateral constriction at about the middle of the distal half of the bone. On the internal lateral surface of the proximal end there is a flat rugose area, broad proximally, but narrowed distally, which disappears toward the middle of the shaft. The internal, proximal, lateral angle is so shaped as to fit nicely into the cavity on the external lateral surface of the proximal end of mc. II, causing an interlocking of the proximal ends of these bones. The proximal articular surface is subtriangular in outline through the external superior lateral angle of the proximal end being produced into a strong triangular process which overlies a corresponding projection on the internal inferior lateral angle of mc. IV. The external outer margin on this process on mc. III presents a rounded articular surface which fits into a deep groove on the superior internal surface of mc. IV, thus causing these bones to interlock at their proximal ends, though somewhat less perfectly than mcs. I and II, and II and III. The palmar surface of mc. III is rugose and there is a broad median ridge continued throughout the entire length of the bone. The distal end is broad and deep, convex, and with an indistinct groove inferiorly."

"Metacarpal IV is shorter and more slender than mc. III. It is greatly constricted medially and at the point of greatest constriction it is nearly circular in cross-section instead of flat as in mcs. II and III. On the internal lateral surface of the proximal end there is the deep groove mentioned above for the accommodation of a corresponding prominence on the external lateral surface of mc. III. The proximal articular surface is triangular. The lines bounding the internal and superior borders are of equal length and meet at right angles so as to form the base and perpendicular of a right-angled triangle, while the hypotenuse is formed by the line bounding the external lateral border. The latter, when this bone is placed in its natural position, runs obliquely downward and inward toward the median axis of the foot. There is a broad, shallow emargination on the external lateral surface near the proximal end. The distal end presents a broad and deep articular surface concave transversely and convex supero-inferiorly."

"Metacarpal V is shorter and stronger than mc. IV. It has something of the general shape of mc. I, though not nearly so massive as that bone. It is compressed proximally, but expands distally. There is a broad, rugose, concave surface on the internal side of the proximal end. The proximal articular surface is crescentric in outline with the upper arm heavier than the lower. There is a deep constriction

on the inferior side and another less pronounced on the superior just behind the distal end. The distal articular surface is faintly convex and subcircular in outline."

"The manner in which the different elements of the metacarpus interlock at their proximal ends is suggestive of that which obtains in the mammalia and is well calculated to give stability to the manus when supporting the weight of the ponderous body. It will also, now that the position of each is definitely known, furnish important aid in assigning the various metacarpals when found disassociated to their proper positions."

"*The Phalanges.*—The entire series of proximal phalanges are present as is also the second or terminal phalanx of the first digit."

"The proximal phalanx of the first digit is longer on the external than on the internal side, so that when in position between the ungual and mc. I it appears wedge shaped, with the wedge directed toward the opposite foot. The internal lateral surface is convex and the external deeply concave. The palmar surface is produced posteriorly into a thin sheet which lies under the distal end of mc. I. The proximal articular surface is concave supero-inferiorly and there is a low, broad keel for articulation with the groove in the distal articular surface of mc. I. The distal articular surface is regularly convex supero-interiorly and concave transversely."

"The ungual of the first digit is compressed laterally but deep posteriorly. The internal lateral surface is convex, the external flat. The proximal articular surface has been so much distorted by pressure, due to the position in which it lay when imbedded, that its characters are obscured in the present specimen. The distal extremity is pointed and the entire external surface throughout the distal two-thirds of its length bears evidence of its having borne a powerful claw during the life of the individual."

"The proximal phalanx of the second digit is much the largest of the entire series. The proximal articular surface is flat and circular in outline, the vertical and lateral diameter of this end of the bone being equal. Distally this phalanx is much depressed and greatly expanded transversely. The distal articular surface is very broad but shallow and divided by a deep, median, vertical groove into two subequal lateral moieties with smooth convexly rounded surfaces. This phalanx, as well as its metacarpal, has been erroneously considered as belonging to the third instead of the second digit of the series by Professor Osborn, as will readily appear by a reference to fig. 7 of that author's paper on the 'Fore and Hind Limbs of Carnivorous and Herbivorous Dinosaurs,' published as Article XI of Vol. XII of the 'Bulletin of the American Museum of Natural History.'"

"The proximal phalanx of the third digit is short, very much depressed, more especially at the distal end, and expanded laterally. The proximal articular surface is elliptical in outline, slightly concave, with its transverse diameter about double that of the vertical. The distal articular surface is broad, but extremely shallow. There is a broad but very shallow depression in the middle, faintly dividing it into two ill-defined articular areas. The bone is of about equal transverse dimensions throughout its length."

"The proximal phalanx of the fourth digit is short and stout, much narrower than that of the third, but not so depressed. Seen from above it appears somewhat wedge-shaped, the length of the external lateral border greatly exceeds that of the internal. The proximal articular surface is slightly concave and semicircular in outline. The distal end is depressed, with an ill-defined articular surface crossed by a shallow, median vertical groove."

"The proximal phalanx of the fifth digit is more massive than that of either the third or fourth, but smaller than the corresponding bones of digits one and two. Seen from above, it presents a broadly wedge-shaped superior surface with an extended external lateral margin, while the inner margin is reduced to a sharp ridge where the proximal and distal surfaces converge and meet at an acute angle. The bone is broader and less depressed than either of the two elements last described. The proximal articular surface is irregularly quadrangular in outline, the transverse dimension about double the vertical. Distally there is a poorly defined articular surface."

The principal dimensions of the phalanges found with this limb and manus are given in the table, page 226.

"*The Sesamoids.*—A small, oblong rounded sesamoid was found in position on the palmar side, lying between the distal end of mc. III and its proximal phalanx. There is little doubt that digits II and IV at least bore similar sesamoids in the same position, while others may have been interposed between some of the phalanges. It is not at all impossible that the small ossicles mentioned by Osborn and Granger as found associated with other elements of the manus of *Diplodocus* and referred by those authors to the carpus were in reality phalangeal sesamoids, as is evidently the case with the present ossicle. The maximum lateral dimension of this bone is 60 mm., vertical 26 mm., while the fore and aft diameter exactly equals the vertical."

Pelvis

The pelvis is represented by the left ilium, left pubis and both ischia. All of these bones are uncrushed and in excellent preservation.

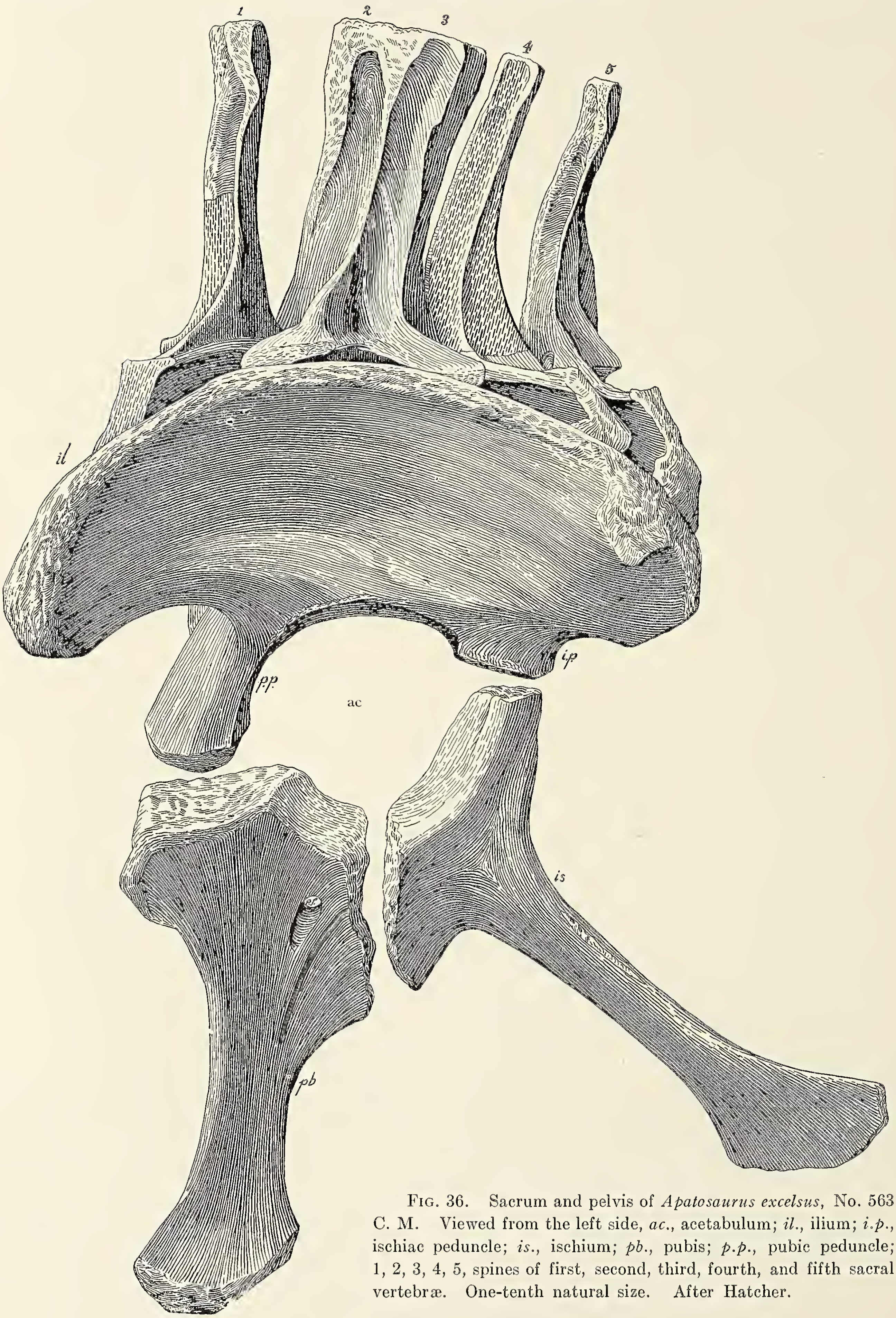

Fig. 36. Sacrum and pelvis of *Apatosaurus excelsus*, No. 563 C. M. Viewed from the left side, *ac.*, acetabulum; *il.*, ilium; *i.p.*, ischiac peduncle; *is.*, ischium; *pb.*, pubis; *p.p.*, pubic peduncle; 1, 2, 3, 4, 5, spines of first, second, third, fourth, and fifth sacral vertebræ. One-tenth natural size. After Hatcher.

Ilium.—The left ilium was found articulated with the sacral vertebræ as shown in fig. 36, and its relationships to the sacrum may be regarded as perfectly normal, since there is no evidence of distortion or displacement. If this assumption is correct, it is in perfect agreement with the Field Museum specimen, in showing the tops of the diapophysial processes above the top border of the ilium, and with having the sacral centra almost entirely hidden by it in a lateral view.

The ilium is produced far in front of the pubic peduncle into a gradually narrowing blade that turns slightly outward and decidedly downward. The lower border of this blade forms an acute angle with the anterior border of the pubic peduncle, as in the Field Museum specimen. In this respect both specimens are quite unlike the nearly right-angled notch found in the ilia of the types of *A. louisæ* and *A. excelsus.*

The pubic peduncle is relatively shorter than in *A. louisæ*, although in all other respects the two bones are very similar.

Pubis.—The pubis is elongate, with massive expanded ends, especially the proximal. The acetabular surface is broad as is the articular surface for the pubic peduncle of the ilium. That there was a tendency, in this specimen, for the pubis to coössify with the peduncle is evidenced by the upward extension of the lateral

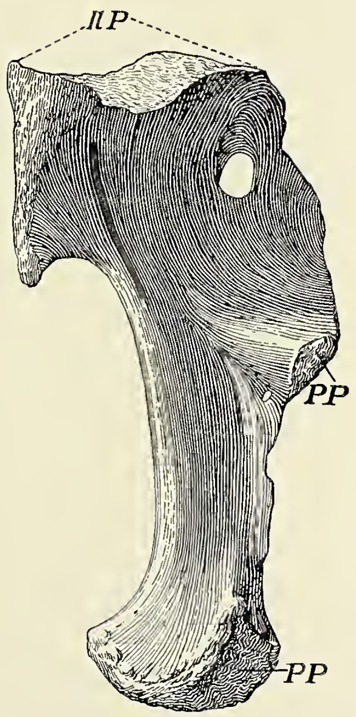

FIG. 37. Left (reversed) pubis of *Apatosaurus excelsus*, No. 563 C. M. Internal view. *il.p.*, articular surface for pubic peduncle; *p.p.*, articulating surfaces for union with opposite pubis. One-tenth natural size.

surfaces of the pubis as shown in fig. 37. A pelvis of *Diplodocus*, No. 94 C. M., shows a similar but more exaggerated condition.

Posteriorly the pubis unites by its thinned margin with the ischium and in this specimen, unlike the *A. louisæ* type, there is no indication of coössification. The posterior margin, below the ischiac border, curves strongly inward and the center presents a thickened ovate rugose surface for union with the pubis of the opposite side. On the inner side of the distal end is a larger rugose surface that, with the one described above, forms the main part of contact between the two pubes on the medial line. It seems quite probable that this union was a cartilaginous one, since in none of the available specimens is there evidence of coössification. Between these two contact points the inner border presents a thin, sharp edge. When the pubes are articulated these intermediate borders are not in contact but leave a narrow slot-like interval between. The distal end presents a roughened surface that may have been capped with cartilage. The pubic foramen is entirely closed in by bone and, viewed from the outer side, passes upward through the bone immediately below the anterior acetabular border.

Ischium.—The ischia are more elongate than the pubes. The proximal end is widely expanded with articulating surfaces for union with the pubis and the ischiac peduncle of the ilium is shown in fig. 36. The proximal end between these articulations forms the postero-inferior boundary of the acetabulum. The shaft is relatively slender and toward the expanded distal end the bone is trihedral in cross-section. When articulated, see fig. 31, the ischia curve strongly inward to meet on the median line. In *A. louisæ*, where they are coössified, the ischia meet for half their length. In this specimen, however, their junction would be somewhat shorter, as these ischia give no evidence of coalescence. If fully articulated the two bones would form a shallow trough on the upper side, and a broadly rounded inferior surface.

The principal feature of this bone is clearly shown in figs. 31 and 36. Their dimensions are given on page 229.

DISCUSSION OF THE GENUS *APATOSAURUS*

The genus *Apatosaurus* was proposed by Professor O. C. Marsh in December 1877, when he briefly described *Apatosaurus ajax*,[46] the genotype, based upon a considerable portion of a skeleton. In this same paper the species *A. grandis* was also briefly described. Two years later the genus was further characterized, largely on the narrowness of the blade of the scapula, the quadrangular shape of

[46]Marsh, O. C., Amer. Jour. Sci., 3d ser., XIV, 1877, p. 514.

the coracoid, and the presence of three coössified vertebræ in the sacrum. All of these bones were illustrated.[47] In this same paper a third species *A. laticollis* was named. In 1915 Holland added a fourth species, *A. louisæ*, based on the skeleton here described.

In 1917 Mook named a fifth species, *A. minimus*, based on a sacrum with attached ilia.

In 1903, Riggs[48] in order to identify a specimen secured by him and now mounted in the Field Museum of Natural History, Chicago, made a study and comparison of the types of *Apatosaurus* and *Brontosaurus* and reached the conclusion that the type "*Apatosaurus* specimen is merely a young animal of the form represented in the adult *Brontosaurus* specimen." . . . . "As the term '*Apatosaurus*' has priority, '*Brontosaurus*' will be regarded as a synonym."

In regard to the species he says: "The species *A. ajax* cannot be recognized in the adult; *A. excelsus* is probably a synonym of *A. laticollis; A. amplus* is valid."

After reviewing the evidence in this whole matter in conjunction with this study of the very complete type skeleton of *Apatosaurus louisæ*, and of other specimens in the Carnegie Museum, I find no reasons for not accepting the determination of Riggs as being a correct and logical interpretation of the facts.

Although it is outside the scope of the present paper to attempt a revision of the genera or of the several described species, the acceptance of the above mentioned conclusion will explain my reference to specimens in the text as *Apatosaurus excelsus* (Marsh) instead of using the better and more widely known term of *Brontosaurus*.

The following species have been referred to *Apatosaurus:*

Apatosaurus ajax Marsh 1877
A. grandis Marsh 1877 = *Morosaurus grandis* 1879 =
    Camarasaurus grandis 1921
A. laticollis Marsh 1879
A. excelsus (Marsh) 1879
A. amplus (Marsh) 1881
A. louisæ Holland 1915
A. minimus Mook 1917[49]

The number of these species that may be considered valid can only be determined by a careful study and comparison of the type specimens which will be

[47]Ibid., XVII, pp. 86-88, Pl. IV, fig. 1, 1879.

[48]Riggs, E. S., Field Columbian Museum, Pub. 82, Geol. ser., 1903, II, No. 4, p. 170.

[49]Mook, C. C., Bull. Amer. Mus. Nat. Hist., XXVII, 1917, Art. XVI, pp. 357-358, fig. 1.

done by Prof. H. F. Osborn and his associates who have a monographic study of the Sauropoda in preparation.

In this connection, however, attention should be called to a recent paper by Dr. F. von Huene,[50] in which he recognizes only three species in the genus *Apatosaurus*, i.e., *A. ajax*, *A. montanus* and *A. louisæ*. He regards the genera *Brontosaurus* and *Atlantosaurus* both to be synonyms of *Apatosaurus*. In this treatment of the genera he is obviously in error, for if the species *montanus* (originally *Atlantosaurus montanus*) is to be retained as a valid species, the genus *Atlantosaurus* must also be retained since it has priority over *Apatosaurus*. That the genus *Apatosaurus* should eventually prove to be a synonym of *Atlantosaurus* is not improbable. For the present, however, I propose to continue the use of *Apatosaurus* and shall regard the species *excelsus* as also being valid.

SUMMARY OF THE OSTEOLOGICAL FEATURES OF THE GENUS *APATOSAURUS*

Skull and *jaws* not certainly known.

Vertebral column composed of one hundred and fourteen vertebræ, divided as follows: Fifteen cervicals; ten dorsals; five sacrals; eighty-two caudals. Cervicals beginning with the sixth have divided spines; cervicals with heavy coalesced cervical ribs; cervicals reaching greatest length in the eleventh. Dorsal vertebræ heavy; spines posterior to the sixth, simple, high; anterior spines strongly divided; capitular facet retained on either third or fourth dorsal centrum; centra all opisthocœlus; sacrum with tall spines, from two to four fused into a plate; anterior caudals with tall simple spines; development of caudal ribs moderate disappearing posteriorly between eleventh and fifteenth vertebræ; anterior vertebræ short; all massive; true pleurocœls absent, distal caudals rod-like.

Ribs of thorax long and heavy; cervical ribs short, seldom equaling length of centrum, very robust, with or without projecting process in front of tuberculum.

Pelvis; pubis, heavy; pubic foramen closed, ischium with expanded distal end, often coalesced with ischium.

Pectoral arch; scapula with little expansion of distal end.

Carpus with one ossified carpal (scapho-lunar) found above metacarpals II, III, and IV.

Manus with five digits; clawed ungual on digit I; phalangial formula, 2, 2, 2, 1, 1.

Femur stout; fourth trochanter above middle.

Tibia stout with heavy recurved outer process; tibia and fibula less than length of femur.

Tarsus with one ossified tarsal, the astragalus; calcaneum absent.

Pes with five functional digits, first three bear unguals; first metatarsal stout, phalangial formula 2, 3, 4, 2, 1.

[50]Huene, F. v., Monog. zur. Geol. und Paleont., p. 288, 1932.

DISCUSSION OF THE SPECIES

After a study of the two specimens of *Apatosaurus* considered in the preceding pages it is my conclusion that they represent two distinct species, *Apatosaurus louisæ* Holland and *A. excelsus* (Marsh) both of which can be adequately characterized. Whether they can be satisfactorily distinguished from the other described species of the genus, inadequately known at the present time, must await a restudy of the type materials, an investigation beyond the scope of the present paper.

In a preliminary paper[51] by Hatcher based on portions of specimen No. 563 C. M., no attempt was made to identify it as to species. It was referred by him to *Brontosaurus* here regarded as a synonym of *Apatosaurus*. After study and a comparison of this specimen, bone by bone, with a considerable number of unpublished plates illustrating skeletal parts of the type of *Brontosaurus excelsus*, that were available to me, such close agreement was found in their essential characteristics as to leave no doubt of their being conspecific. Furthermore, this specimen was found to be in almost full accord with the Field Museum specimen so well described and illustrated by Riggs,[52] which was identified by him as pertaining to the species *A. excelsus* after a study of the type skeleton in the Peabody Museum.

In establishing[53] the species, *A. louisæ*, Holland briefly listed those skeletal characters which in his estimation distinguished this species from *A.* (*Brontosaurus*) *excelsus* of Marsh.

In condensed form these were as follows:

1. Higher position of the pleurocœls on the side of the centra of the dorsal vertebræ.
2. A reduction in number of the anterior dorsal vertebræ having strongly developed hemispherical balls.
3. Non-fenestration of the transverse processes of the anterior caudals.
4. Higher position of the parapophysial facets of the dorsal vertebræ.
5. More perpendicular position of the spines of the mid-caudal vertebræ.

It is now possible to strengthen this preliminary characterization with additional skeletal features that taken together appear to adequately distinguish this species. These are graphically contrasted in the parallel columns below.

[51]Hatcher, J. B., Annals Carnegie Museum, I, 1902, pp. 356-376.

[52]Riggs, E. S., Field Columbian Museum, Geol. Ser., Vol. II, No. 4, 1903, pp. 165-196.

[53]Holland, W. J., Annals Carnegie Museum, vol. X, 1915, pp. 144-145.

APATOSAURUS LOUISÆ

1. Cervical Vertebræ.
   (a). Cervical ribs without forwardly projecting process.
   (b). Infrapostzygapophysial cavity posterior to C5, undivided by accessory lamina.

2. Dorsal Vertebræ.
   (a). Relatively slender transverse processes on anterior half of dorsal series.
   (b). Capitular facet reaches extreme height on D5.
   (c). Hyposphen-hypantrum articulation first appears on D3.
   (d). Hyposphen reaches its maximum development on D4.
   (e). Transverse and vertical diameters of posterior end of centra subequal.
   (f). Centrum of D2 longest of series.

3. Caudal Vertebræ.
   (a). Transverse processes of anterior caudals not perforated by fenestra.
   (b). Spines of mid caudal region more erect.
   (c). Vertical diameter of anterior caudal centra greater than transverse diameter.
   (d). Caudal spines slender.

4. Sacrals.
   Sacral ribs articulating only with half the length of the sacral centra.

5. Scapula.
   (a). Spine diagonal to axis of greatest length.
   (b). Muscular fossa above spine much reduced.
   (c). Distal portion of blade but little expanded.

APATOSAURUS EXCELSUS

1. Cervical vertebræ.
   (a). Cervical ribs with a forwardly projecting process.
   (b). Infrapostzygapophysial cavity posterior to C5, subdivided by accessory lamina.

2. Dorsal Vertebræ.
   (a). Relatively heavy transverse processes on anterior half of dorsal series.
   (b). Capitular facet reaches extreme height on D6.
   (c). Hyposphen-hypantrum articulation first appears on D4.
   (d). Hyposphen reaches its maximum development on D6.
   (e). Transverse diameter of centra exceeds vertical diameter.
   (f). Centrum of D1 longest of series.

3. Caudal Vertebræ.
   (a). Transverse process of anterior caudals perforated by fenestra.
   (b). Spines of mid caudal region less erect.
   (c). Diameters of anterior caudals subequal.
   (d). Caudal spines stout.

4. Sacrals.
   Sacral ribs articulating with full length of sacral centra.

5. Scapula.
   (a). Spine at right angles to axis of greatest length.
   (b). Muscular fossa above spine large.
   (c). Distal portion of blade somewhat expanded both anteriorly and posteriorly.

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EXPLANATION OF PLATE XXI.

FIG. 1. Dinosaur National Monument Quarry. The series of caudal vertebræ of *Apatosaurus louisæ* (No. 3018 C. M.) in the middle foreground was the initial discovery that led to the development of this great quarry. In uncovering this skeleton of *Apatosaurus* other specimens were encountered and so it continued during the entire thirteen years that collecting was carried on here by the Carnegie Museum.

FIG. 2. A complete backbone of *Apatosaurus* (Quarry No. 160, Cat. No. 3378 C. M.) in the process of exhumation by Carnegie Museum collectors. The four-foot squares outlined on the rock face are for the purpose of accurately plotting the fossils on the quarry map.

FIG. 3. Showing the method of removing large blocks of plaster-encased bones from the quarry to a point accessible to wagons.

FIG. 4. Removing the overburden from the face of the fossil-bearing sandstone on the east side of the quarry. The late Dr. W. J. Holland standing at the entrance to the excavation.

FIG. 5. Showing the method used in lowering large bones from the steeply inclined face of the quarry by use of block and fall.

FIG. 6. Face of quarry showing a specimen of *Diplodocus* (Quarry No. 150) partly uncovered. The large size of the bones is indicated by comparison with the man seated in the right foreground.

FIG. 7. General view, looking eastward from the Dinosaur National Monument Quarry toward Split Mountain.

FIG. 8. Showing one of the methods used in handling the heavy blocks of stone enclosed fossils.

All photographs by Earl Douglass.


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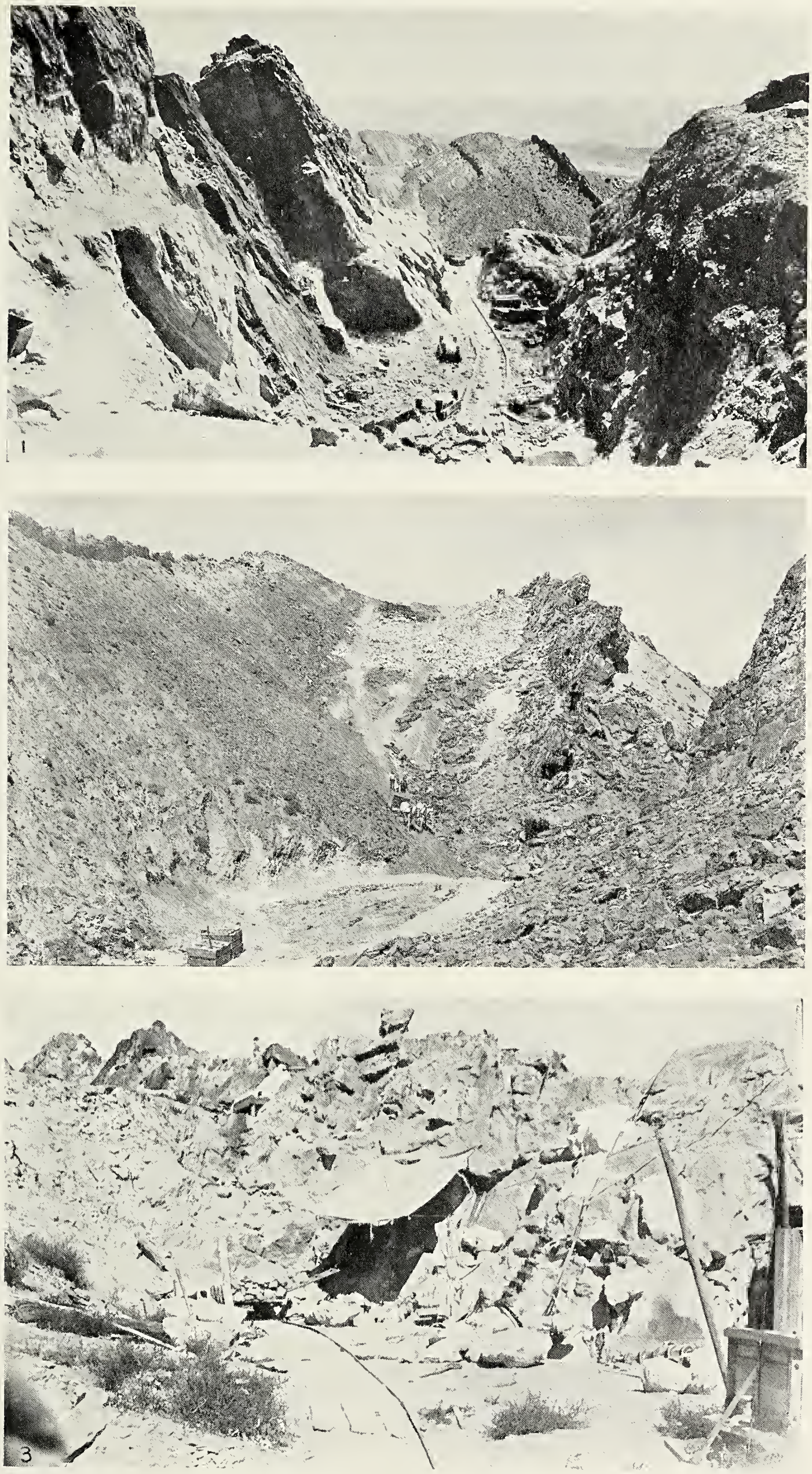
EXPLANATION OF PLATE XXII.

FIG. 1. Dinosaur National Monument Quarry looking toward the east. The fossil-bearing layer has been largely removed from the sloping wall on the left of the picture. The track was used for a mine car on which debris was removed to the dump.

FIG. 2. Looking upward to the east end of the Dinosaur Quarry, showing trail down which boxes of specimens were dragged. The dump may be seen in the upper middle of the picture, and boxes of specimens ready for shipment in the lower foreground.

FIG. 3. East side of Dinosaur Quarry, as it appeared at the time of suspension of work by the Carnegie Museum collectors. The skeleton (*Diplodocus*) in the rock at the right of the photograph was turned over to the Smithsonian Institution in 1923. The vertebræ (*Barosaurus*) under the canopy were collected by the University of Utah and are now in the American Museum of Natural History, New York City. All photographs by Earl Douglass.



EXPLANATION OF PLATE XXIII.

Quarry map of the Dinosaur National Monument, showing the position of the skeleton of *Apatosaurus louisæ*, and the relative positions of all important specimens collected there.

On the map the horizontal lines are lettered and the perpendicular lines are numbered. The numbers indicate the number of feet distant from a zero line near the middle of the quarry. For example, 4, 8, and 12, etc., indicate distances west of zero, and E 4, E 8, E 12, etc., indicate distances east of the zero line. To locate a specimen on the map such as the type of *Apatosaurus louisæ*, it will be found to lie in the intersection of perpendicular lines 4 to 56 and the horizontal lines D to H.

Specimens were numbered consecutively as found, beginning with No. 1, which is the *A. louisæ* skeleton. Likewise the scattered bones of an individual were also numbered. Thus a bone of specimen No. 25 might be assigned the number 10, if so, it would be designated $\frac{25}{10}$; occasionally letters were used, then this same bone would be designated $\frac{25}{B}$. So far as it was feasible to do so, in the field, a single number was applied to all parts of an individual. Below is a list of the more important identified specimens, accompanied by the letters and figures which locate them on the map.

LIST OF THE MORE IMPORTANT SPECIMENS AS SHOWN ON THE QUARRY MAP.

Quarry No.		Cat No.	Location on Map
1	*Apatosaurus louisæ* Holland Type	3018 C. M.	D to H. & 4-56
24	Herbivorous dinosaur (small)		G-46
26	*Dryosaurus altus* Marsh	3392 C. M.	A-15e
39	*Stegosaurus* sp.		A to F-10-20e
40	*Apatosaurus*?		B to E-2-W 48
58	*Glyptops utahensis* Gilmore Type	3412 C. M.	E-36
60	*Diplodocus* sp. sk. and mandible	11161* C. M.	C to D-36
89	Sauropod		BC-8
90	*Diplodocus* sp.		E-9
95	*Glyptops*	3411 C. M.	C-52
130	Sauropod		B-56
145	Sauropod		E-88
150	*Diplodocus* sp.		C-100
150B	*Barosaurus* (Skeleton)		C-100
154	*Glyptops utahensis* Gilmore Paratype	3380 C. M.	E-136
155	*Diplodocus* sp.		E-108
160	*Diplodocus*-like skull	11162 C. M.	C to G-116-156
160	*Apatosaurus* sp. complete vertebral series	3378 C. M.	F-140
202	*Antrodemus* sp.		B to C-96
210	Sauropod		Z to B-76-102
214	Sauropod (small)		B-122
220	*Diplodocus* sp. (skull, neck)	3452 C. M.	Y to B-112-117
230	Crocodile (skull)		Y-130
240	*Camarasaurus* sp.	11393 C. M.	Y-132
272	Turtle		V-144
301	*Camarasaurus* sp.		A to D-36-E
310	*Brachyosaurus*?		D to F-40e
324	*Camarasaurus* sp.		E-65e
325	*Uintasaurus douglassi* Holland Type	11068 C. M.	A-46e
333	*Camarasaurus lentus* (Marsh) (skeleton)		A-72e
340	*Barosaurus* sp. skeleton in Amer. Mus. Nat. Hist.		U to X-116e
350	*Stegosaurus* sp.		X-108e
355	*Diplodocus longus* Marsh in U. S. Nat. Mus.	10865 U. S. N. M.	V-128e
360	*Laosaurus gracilis* Marsh	11340 C. M.	U-101e
351	*Diplodocus* sp. skull small	11255 C. M.	U-156e
370	*Camptosaurus medius* Marsh (skeleton)	11337 C. M.	V-94e

*Gilmore, C. W. Memoirs Carnegie Museum, vol. X, No. 3, 1925, erroneously refers to this skull as No. 11255 C. M.


MAP OF
DINOSAUR NATIONAL MONUMENT QUARRY
UTAH
Scale 10 feet

EXPLANATION OF PLATE XXIV.

Cervical vertebræ of *Apatosaurus louisæ*. Type, No. 3018 C. M., Cervicals 1 to 15 inclusive. *A.* anterior views; *B.* lateral views; *C.* posterior views; cervicals 6, 7, 8, 9, and 10, have had some of their lateral structure drawn from the right side. Cervicals 13, 14, and 15, have been much restored from badly crushed originals, and should be used with caution.

A. C., anterior convexity.
A. L., accessory lamina.
At., Atlas.
Ax., Axis.
Cv. R., Cervical rib.
Di., Diapophysis.
H. L., Horizonal lamina.
Id. C., Infradiapophysial cavity.
Ipod. L., Infrapostdiapophysial lamina.
Ipoz. C., Infrapostzygapophysial cavity.
Ipoz. L., Infrapostzygapophysial lamina.
Iprd. L., Infraprediapophysial lamina.
Iprz. C., Infraprezygapophysial cavity.
Iprz. L., Infraprezygapophysial lamina.
Itrpoz. L., Intrapostzygapophysial lamina.
Itrprz. L., Intraprezygapophysial lamina.
Pa., Parapophysis.
Pl., Pleurocœl.
Psp. C., Postspinal cavity.
Poz., Postzygapophysis.
Prz., Prezygapophysis.
Spoz. L., Suprapostzygapophysial lamina.
Sprz. L., Supraprezygapophysial lamina.

All one-tenth natural size.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Iprz C
Id C
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Spoz L
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Sprz L
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Ipod L
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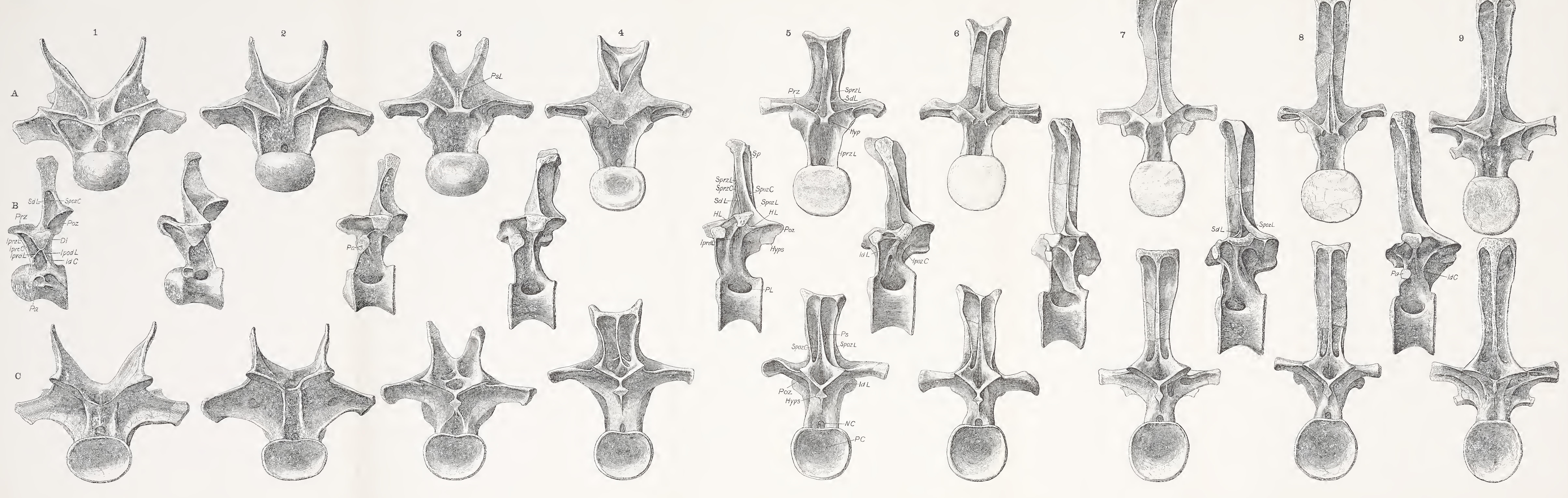
Ipoz L
Pl
ScL
Pa
CvR
Itrpoz L
PC

EXPLANATION OF PLATE XXV.

Dorsal vertebræ of *Apatosaurus louisæ*, Type, No. 3018 C. M. Dorsals 1 to 9 inclusive. *A.* anterior views; *B.* lateral views; *C.* posterior views. The figures indicate dorsals 1 to 9 respectively.

A. L., accessory lamina.
Di., diapophysis.
H. L., horizonal lamina.
Hypn., hypantrum.
Hyps., hyposphen.
Id. C., infradiapophysial cavity.
Id. L., infradiapophysial lamina.
Ipod. L., infrapostdiapophysial lamina.
Ipoz. C., infrapostzygapophysial cavity.
Iprd. L., infraprediapophysial lamina.
Iprz. C., infraprezygapophysial cavity.
Iprz. L., infraprezygapophysial lamina.
Me., metapophysis.
N. C., neural canal.
P. C., posterior concavity or cup.
Pa., parapophysis.
Pl., pleurocœl.
Poz., postzygapophysis.
Prz., prezygapophysis.
Ps. L., prespinal lamina.
Sd. L., supradiapophysial lamina.
Sp., spine.
Spoz. C., suprapostzygapophysial cavity.
Spoz. L., suprapostzygapophysial lamina.
Sprz. C., supraprezygapophysial cavity.
Sprz. L., supraprezygapophysial lamina.

All one-tenth natural size.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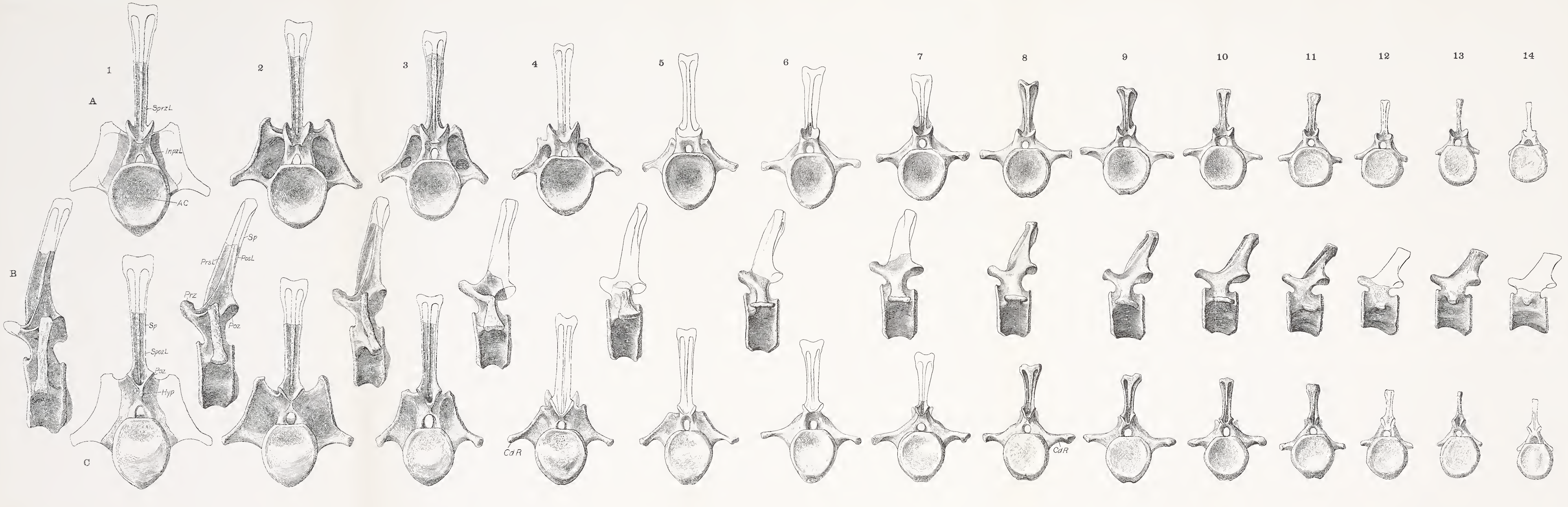
SpozL
IdL
Poz
Hyps
NC
PC

EXPLANATION OF PLATE XXVI.

Caudal vertebræ of *Apatosaurus louisæ.* Type, No. 3018 C. M. Caudals one to fourteen inclusive. *A.* anterior view; *B.* lateral view; *C.* posterior views.

A. C., anterior concavity or cup.
Cd. R., Caudal rib.
Hyp., Vestigal hyposphen.
Iprz. L., infraprezygapophysial lamina.
N. C., Neural Canal.
Pos. L., Postspinal lamina.
Poz., Postzygapophysis.
Prs. L., Prespinal lamina.
Prz., Prezygapophysis.
Sp., Spine.
Spoz., Suprapostzygapophysial lamina.
Sprz. L., Supraprezygapophysial lamina.

All one-tenth natural size.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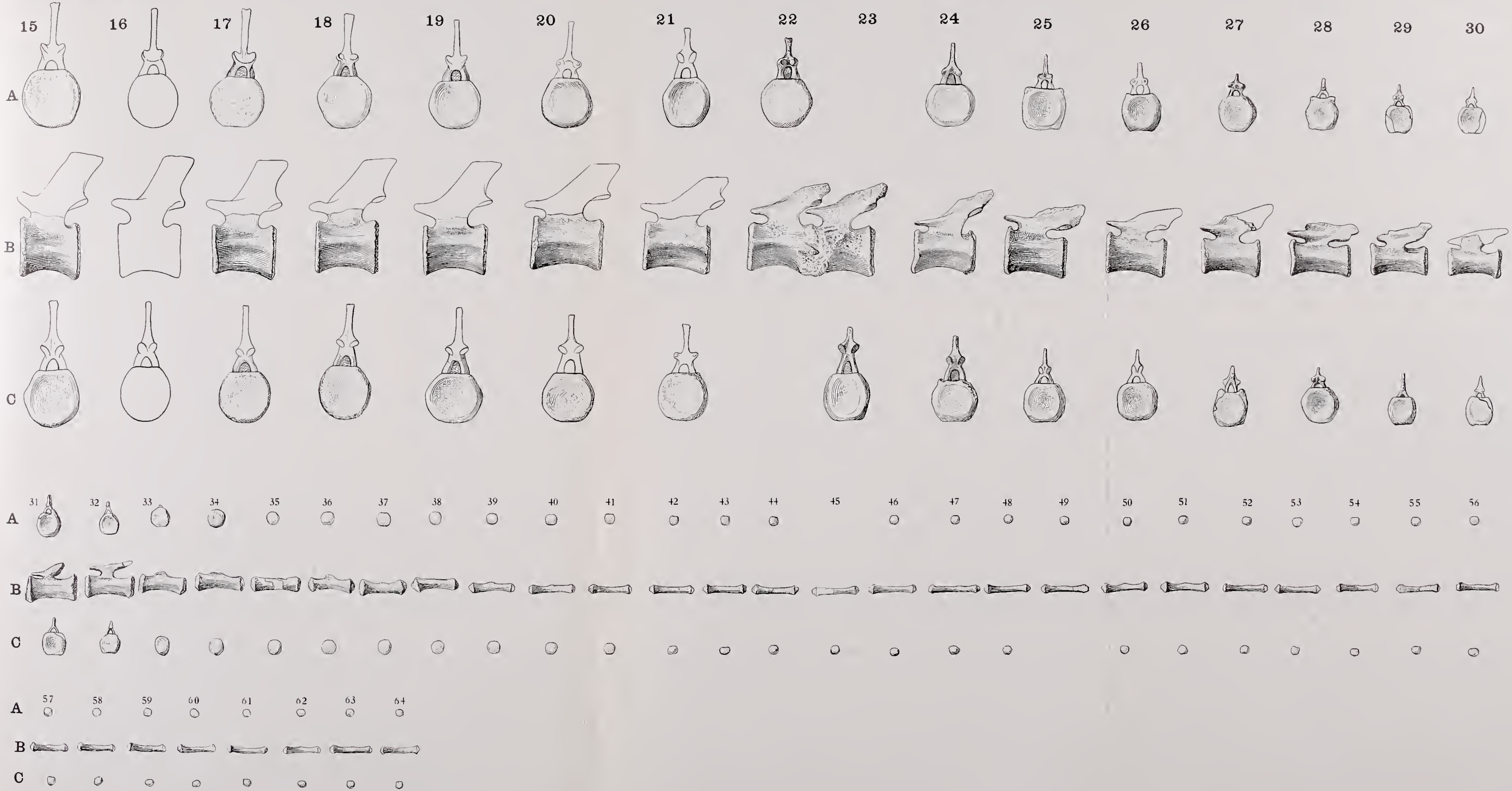
EXPLANATION OF PLATE XXVII.

Caudal vertebræ of *Apatosaurus louisæ*. Type, No. 3018 C. M. *A*. anterior views; *B*. lateral views; *C*. posterior views. The figures 15-64 indicate caudals fifteen to sixty-four respectively.

All one-tenth natural size.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B
C
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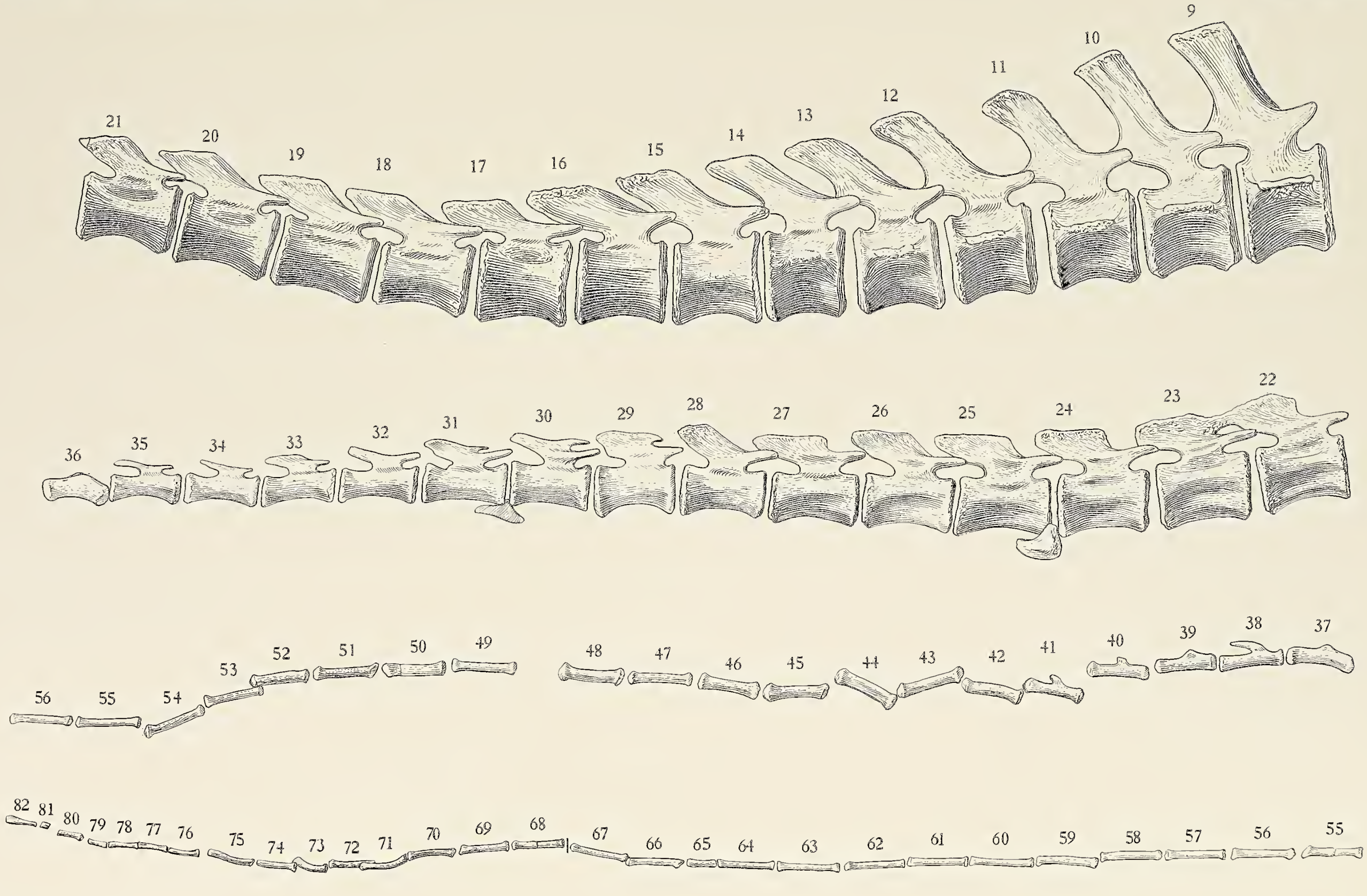
A
B
C
57 58 59 60 61 62 63 64
A
B
C

EXPLANATION OF PLATE XXVIII.

Caudal vertebræ of *Apatosaurus* sp., No. 3078 C. M. Caudals 9 to 82 inclusive. A portion of the complete articulated vertebral series, shown *in situ*, fig. 2., Plate I.

All one-tenth natural size.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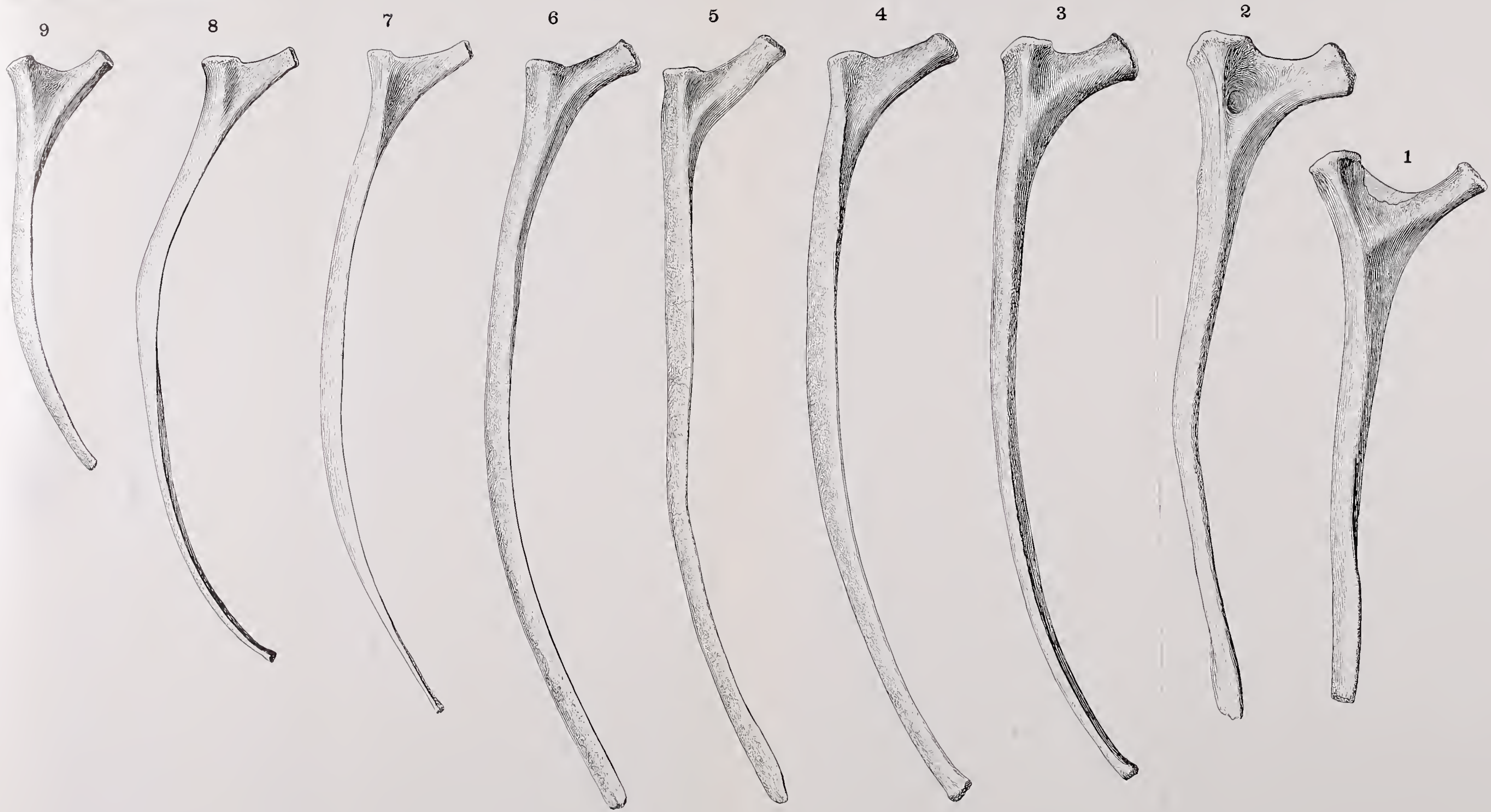
EXPLANATION OF PLATE XXIX.

Dorsal ribs of right side of *Apatosaurus louisæ*. Type, No. 3018 C. M. Ribs one to nine respectively. Viewed from the front.

All one-tenth natural size.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EXPLANATION OF PLATE XXX.

Dorsal ribs of right side of *Apatosaurus louisæ*. Type, No. 3018 C. M. Ribs one to nine respectively. Lateral view.

All one-tenth natural size.


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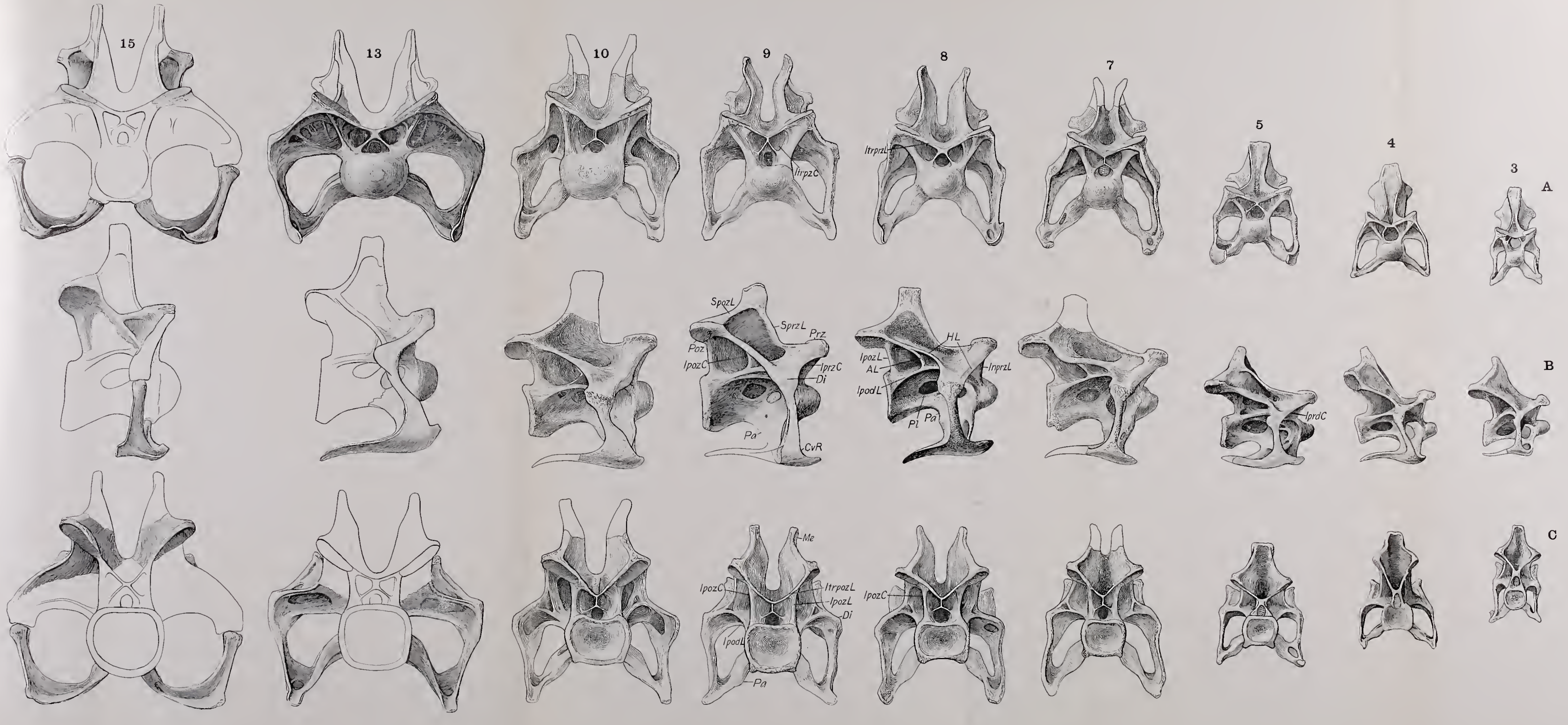
EXPLANATION OF PLATE XXXI.

Cervical vertebræ of *Apatosaurus excelsus*. No. 563 C. M. *A*. anterior views; *B*. lateral views; *C*. posterior views. Cervicals 3, 4, 5, 7, 8, 9, 13?, and 15 respectively. These have been provisionally determined by comparison with the articulated series of *A. louisæ*.

A. C., anterior convexity.
A. L., accessory lamina.
Cv. R., cervical rib.
Di., diapophysis.
H. L., horizontal lamina.
Ipod. L., infrapostdiapophysial lamina.
Ipoz. C., infrapostzygapophysial cavity.
Ipoz. L., infrapostzygapophysial lamina.
Iprd. L., infraprediapophysial lamina.
Iprz. C., infraprezygapophysial cavity.
Iprz. L., infraprezygapophysial lamina.
Intrpoz. L., infrapostzygapophysial lamina.
Itrprz. L., intraprezygapophysial lamina.
Me., metapophysis.
Pa., parapophysis.
Pl., pleurocœl.
Poz., postzygapophysis.
Prz., prezygapophysis.
Spoz. L., suprapostzygapophysial lamina.
Sprz. L., supraprezygapophysial lamina.

All one-tenth natural size.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lpodL
lnprzL
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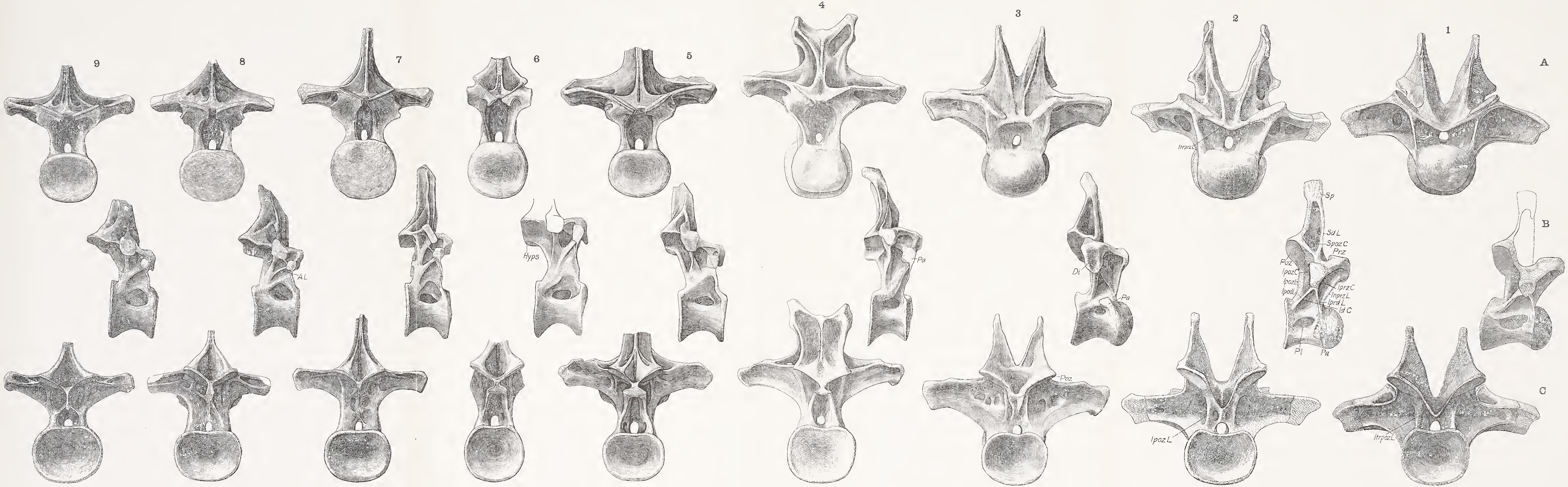
ltrpozL
lpozL
Di
lpodL
Pa
lpozC
C

EXPLANATION OF PLATE XXXII.

Dorsal vertebræ of *Apatosaurus excelsus*. No. 563 C. M. Dorsals 1 to 9 inclusive. *A*. anterior views; *B*. lateral views; *C*. posterior views. The original assoeiation is unknown, so that their arrangement here, espeeially the posterior members may be regarded as provisional. 1, 2, 3, 4, 5, 6, 7, 8, and 9, dorsal vertebræ one to nine respectively.

A. L., aeeessory lamina.
Di., diapophysis.
H. L., horizonal lamina.
Hyps., hyposphen.
Id. C., infradiapophysial cavity.
Ipod. L., infrapostdiapophysial lamina.
Ipoz. C., infrapostzygapophysial cavity.
Ipoz. L., infrapostzygapophysial lamina.
Iprd. L., Infraprediapophysial lamina.
Iprz. C., infraprezygapophysial eavity.
Iprz. L., infraprezygapophysial lamina.
Itrpoz. L., intrapostzygapophysial lamina.
Itrprz. L., intraprezygapophysial lamina.
Pa., parapophysis.
Pl., pleuroeœl.
Pod. L., postdiapophysial lamina.
Poz., postzygapophysis.
Prz., prezygapophysis.
Sd. L., supradiapophysial lamina.
Sp., spine.
Spoz. L., suprapostzygapophysial lamina.
Spoz. Cl., suprapostzygapophysial eavity.
Sprz. L., supraprezygapophysial lamina.

All one-tenth natural size.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Spoz C
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IpozC
IpozL
IpodL
IprzC
InprzL
Iprd L
Id C
Pl
Pa
Di
Hyps
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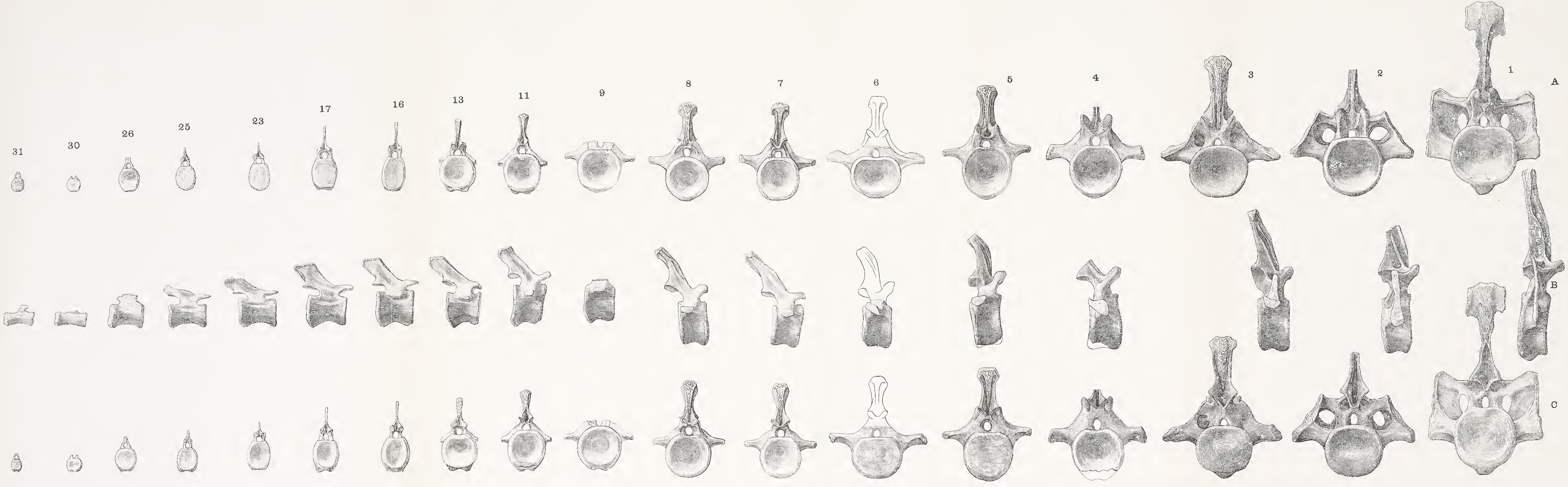
IpozL
ItrpozL

EXPLANATION OF PLATE XXXIII

Caudal vertebræ of *Apatosaurus excelsus*, No. 563 C. M. These vertebræ were found disarticulated and scattered and are tentatively allocated in the caudal series. *A.* anterior view; *B.* lateral view; *C.* posterior view. Numerals 1, 2, 3, 4, 5, 6, 7, 8, 9, 11, 13, 16, 17, 23, 25, 26, 30 and 31, caudal vertebræ one to nine, eleven, thirteen, sixteen, seventeen, twenty-three, twenty-five, twenty-six, thirty and thirty-one respectively.

All one-tenth natural size.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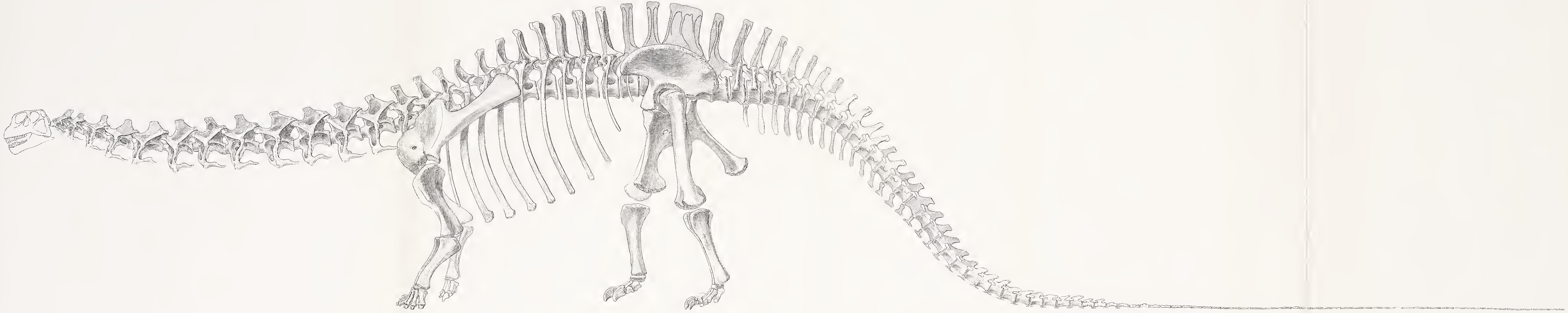
EXPLANATION OF PLATE XXXIV.

Restoration of the skeleton of *Apatosaurus louisæ* Holland. Based primarily on the mounted skeleton (No. 3018) in the Carnegie Museum. Drawn by Mr. Sydney Prentice. The skull is based upon a restored skull in the Carnegie Museum No. 12020, which may pertain to a large *Camarasaurus*.

One-thirtieth natural size.



EXPLANATION OF PLATE XXXV.

Mounted skeleton of *Apatosaurus louisæ* Holland, No. 3018, as exhibited in the Carnegie Museum. The mounted skeleton of *Diplodocus carnegii* shown on the left hand side.